The University of Dayton Research Institute

Best Practices for Fuel System Contamination Detection and Remediation

Final Report

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Best Practices for Fuel System Contamination Detection and Remediation

Executive Summary:

Fuel contamination is a broad term commonly applied to anything that causes a fuel test to fail quality assurance testing. Also included as contamination is the presence of any polar phase containing evidence of corrosion products or microbial growth. The Department of Defense, Commercial airlines, NATO, ASME and other organizations provide guidance on periodic product sampling and testing to ensure fuel quality. Guidance for contamination identification, however, is quite limited. This study was undertaken to investigate best practices for sampling, analyzing and reporting procedures utilized by fuel system/equipment operators (referred to as field personnel) and laboratory personnel to perform after the presence of fuel contamination is confirmed. The complete listing of Documents examined as part of this study, with a brief description of fuel quality guidance included in each is contained in Attachment 1.

Electronic records from the AFTAT database, (AF Test and Analysis Tool), were examined for instances of QA test failures. The three most frequent test failures were FSII, (Fuel System Icing Inhibitor), content, Particulate Matter, and Thermal Stability with Conductivity a distant fourth. When failures were graphed according to year of occurrence or month of occurrence, no seasonal or yearly trends were observed in contamination events during the seven years examined, (2007 to 2015). Likewise, case studies provided by the Army and Navy also showed no trends and fell into the same categories as AF failures.

Four military facilities were visited to view normal field sampling operations and document potential areas of emphasis for sampling guidance. The installations visited were Location A, Location B, Location C, and Location D. These installations were selected because they represented multiple fueling sites, various levels of bulk storage, helicopter operations, pipeline deliveries, tanker deliveries, fleet refueling, F-24, (Jet A with FSII, Conductivity and Corrosion Inhibitor additives), and JP-5 fuels. While MIL-STD 3004D lists specific testing requirements and intervals, local conditions and infrastructure impose constraints that determine how local operators comply with these requirements. Several occasions were documented where local procedures deviated from established testing protocols. These deviations were discussed with local supervisors and filed with DLA Energy DQ Research and Development. None of the installations had a local contamination plan in place, each location was reliant on advice from Quality Assurance Representatives (QARs), Service Control Point (SCP) or local management/laboratory personnel for appropriate actions to take.

In order to assist fuel laboratory personnel identify particulate contamination, a list of all fuel wetted components in DOD fuel delivery and storage systems was assembled. Additionally, polymeric and elemental composition of various fuel handling and pumping hardware was derived from data contained in the AFCESA HRJ Fuel Study. The results are tabulated in Attachment 2. Epoxy tank and pipeline coatings contain solid fillers to improve durability and color. Material composition of all approved DOD fuel tank and pipeline coatings were collected and tabulated in Attachment 3.

Laboratory filtration filters and inline sample filters were brought back from facility visits for extensive examination at AFRL and UDRI facilities. Several filters from Location D showed very high particle content from pipeline deliveries while filters from the other three installations contained low particulate loading. Two filter – separator elements were returned from the field. One element from Location B had performed for 3 years without excessive loading, while the second, from Location D, was replaced with less than 1 month in service. The results of x-ray, light microscopic, and scanning electron microscopic analysis are documented in Attachment 4.

Without having a plan in place it is difficult to respond appropriately to abnormal occurrences. Additionally, filter replacement and fuel polishing efforts make finding the source of a contaminate difficult or impossible. Initial steps in response to QA test failures should include a systematic process to locate the problem source and extent. A generic response plan that includes basic crisis management principles is included in Attachment 5.

Case histories and anecdotal evidence point toward several re-occurring themes that prevent a full analysis of contamination events. These are "lack of prompt and appropriate sample arriving at the laboratory", and "no single onsite personnel are responsible for organizing a successful effort". The crisis management inspired contamination investigation approach document suggests collecting repeat and retain samples as soon as a significant contamination event is suspected. If initial test failures are replicated, the retain samples will be available for shipment to another laboratory if requested. Upon verification of results at the lab and determining that the contamination may have a significant effect on operations, a local Mitigation Manager would be selected or offsite personnel would be positioned to manage the investigation team.

Sample reports generated by contract laboratories typically explain results in precise descriptive language that may not be easily understandable by field personnel or those without advanced laboratory training. Attachment 6 lists the most common analytical instrumentation used to analyze samples for evidence of contamination along with a brief description of their operation and limitations.

Sampling procedures for QA purposes are explained in detail in existing publications and service directives while procedures for non-standard materials found in fuel systems are not covered. A course of sample acquisition is suggested in Attachment 7 to ensure that contaminant material is available for area laboratory analysis if needed, while allowing simple mitigation efforts to proceed.

Fuel contamination tends to fall into predictable categories. Attachment 8 lists common contaminants along with their general effect on QA test results. This chart may suggest possible sources of contamination to investigate while laboratory analysis is progressing, however, it should not replace full lab analysis for serious contamination events.

Microbial contamination continues to be one of the most poorly diagnosed problems facing the fuel systems examined for this study. Despite an abundance of expert studies documenting the sources and results of uncontrolled microbial contamination, field personnel and area lab personnel continue to perform ineffective testing protocols or test samples that have lost any connection to source contamination. Attachment 9 contains proper sampling protocols and a rationale for establishing levels of microbial activity that signal increased housekeeping efforts are necessary to prevent system degradation. Historical data is used to support a recommendation that IATA guidelines are not appropriate for fuel systems containing F-24 additives. Additional information covers the common test kits commonly used by civilian air carriers.

Best Practices for Fuel System Contamination Detection and Remediation

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Recommendations:

Crisis Management Approach to Contamination Identification and Mitigation:

- The extent and quantity of contamination will determine if it is necessary to implement the full Crisis Management approach, (Attachment 5).
- The first 3 actions:
  - confirm contamination is present
  - determine extent of contamination
  - quarantine affected systems

  should be performed whenever QA testing fails specification or other non-fuel material is present in the fuel delivery system.

QA Testing:

- Require quarterly sampling of storage tank bottoms at the sump with a "true" bottom thief. Line samples may be an adequate substitute for "all level" samples but are unlikely to capture conditions on the tank bottom.
- Require periodic inspections and necessary repairs of all sample acquisition equipment. Combined samples should be created from representative samples from each tank or tank layer. Timed lowering or 'momentarily dipping' of an open bottle into multiple tanks or through multiple tank layers should be discouraged.

Filter – Separator element analysis:

- Ensure that personnel responsible for filter-separator servicing are using proper tools and procedures, to include physical examination of separator elements, whenever filtration elements are replaced for high delta pressure.
- Microscopic evaluation of filter-coalescer elements replaced due to high delta P may provide the definitive definition of contaminant source.
- Filter material should be sampled in strips not isolated rectangular coupons.
- Use of a manual hacksaw should be strongly discouraged in favor of a powered band saw.
- Obtain a powered metal cutting shear, or "nibbler" for removing ends form the metal tube. This is a hand drill size tool that requires little training, has few safety considerations, and produces few if any metal particles.
- Along with operational testing of filters during initial qualification, filter material should be examined to determine which layer is likely to capture given size particle.

Microbial Contamination Testing:

- Additional testing of Army helicopters and Navy aircraft is needed to verify that results from JP-8 testing are applicable across all US military aircraft.
- Records analysis should indicate the most probable airframes to see microbial fouling and an appropriate testing frequency. It would be arbitrary to establish microbial test limits analogous to the IATA test limits without a comprehensive analysis of aircraft fuel cell maintenance and fuel filter "out of cycle" replacement records on line aircraft.
- Filter-Separators tend to concentrate all forms of contamination; water, particulate, and microbial. Periodic testing of filter-separator water bottoms may provide the earliest indication of microbial contaminants in bulk storage tanks and fuel receipts.
- ANY microbial levels, in fuel with normal FSII concentrations, above the nuisance

level of 500 RLU, (Relative Light Units, measurement units used in Adenosine Tri-Phosphate quantification), or an equivalent CFU, (Colony Forming Units, estimate of growth test level should trigger aggressive water removal from all low points and sumps in the fuel delivery system. Daily microbial testing should be continued until results stabilize at levels between 100 and 400 RLU or an equivalent CFU test level.

- Large bulk storage tanks that produce test levels over 10,000 RLU or with visible rag layer on water bottom samples may need to be stirred and filtered for several days in order to ensure a clean fuel delivery.
- Microbial contamination does not develop overnight. Since it may take months to become a serious problem there is little reason to require sampling kits, (described in Attachment 9), at all storage locations. It is more important to take microbial contamination samples correctly than to take them quickly. The most appropriate utilization of these kits would be to position them within overnight shipping distance of the fuel storage facilities. If microbial contamination is suspected, a kit and instructions on proper sampling can be quickly provided. Transit time for the sampling kit will also facilitate finding local personnel who are qualified to properly obtain samples and prepare them for shipment.

Best Practices for Fuel System Contamination Detection and Remediation by Task.

Task 1: Literature search for standard fuel system maintenance procedures and intervals.

An extensive literature search was conducted to identify published procedures that are designed to ensure that quality fuel is delivered to DOD users. With few exceptions, government publications focus on testing fuel to ensure that the required quality is maintained. Little guidance is given for occasions where contamination is found. The extent of direction given, if any, for occasions where fuel contamination is suspected is to verify QA failure and to send a sample to appropriate laboratory for analysis. The most detailed example of direction for a definite fuel contamination event is: "servicing equipment shall be taken out of service and investigative action performed", or "It may be necessary to sample upstream of the filter separator to locate the source of the contaminant"(i). Comprehensive guidance on where to collect samples and what type of sample to collect before beginning mitigation, is needed to preserve the evidence, determine the original contamination source and evaluate the likelihood of a reoccurrence. The complete listing of Documents examined to date with a brief description of fuel quality guidance included in each is contained in Attachment 1.

Task 2: Document standard fuel and sump sampling procedures with normal variations.

Electronic records from the AFTAT database, (AF Test and Analysis Tool), were examined for instances of QA test failures. The three most frequent QA test failures were FSII content, Particulate Matter, and Thermal Stability with conductivity a distant fourth, (Table 1).

FSII	510
Particulate Matter	379
Thermal Stability	343
Conductivity	173
Existent Gum	75
Total Acid Number	68
Flash Point	57
WRIR	53
WSIM	49
Water and Solids	44
Distillation	41
Freezing Point	41
Filtration Time	36
Appearance	29
Vapor Pressure	10
Workmanship	7
Copper Strip Corrosion	2

Table 1: Test failures from Jan, 2007 through April 2015

When failures were graphed according to year of occurrence (Figure 1) or month of occurrence, (Figure 2) no seasonal or yearly trends were observed in contamination events during the seven years examined.

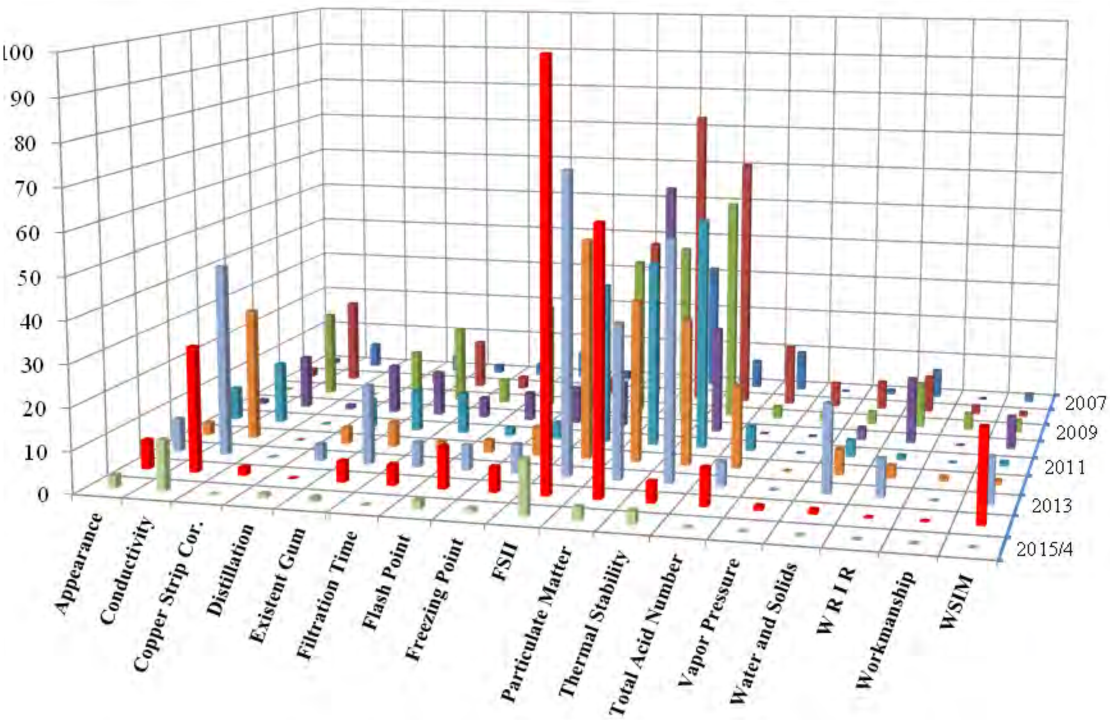

Figure 1. Yearly QA test failures recorded in AFTAT database from 2007 to April., 2015.

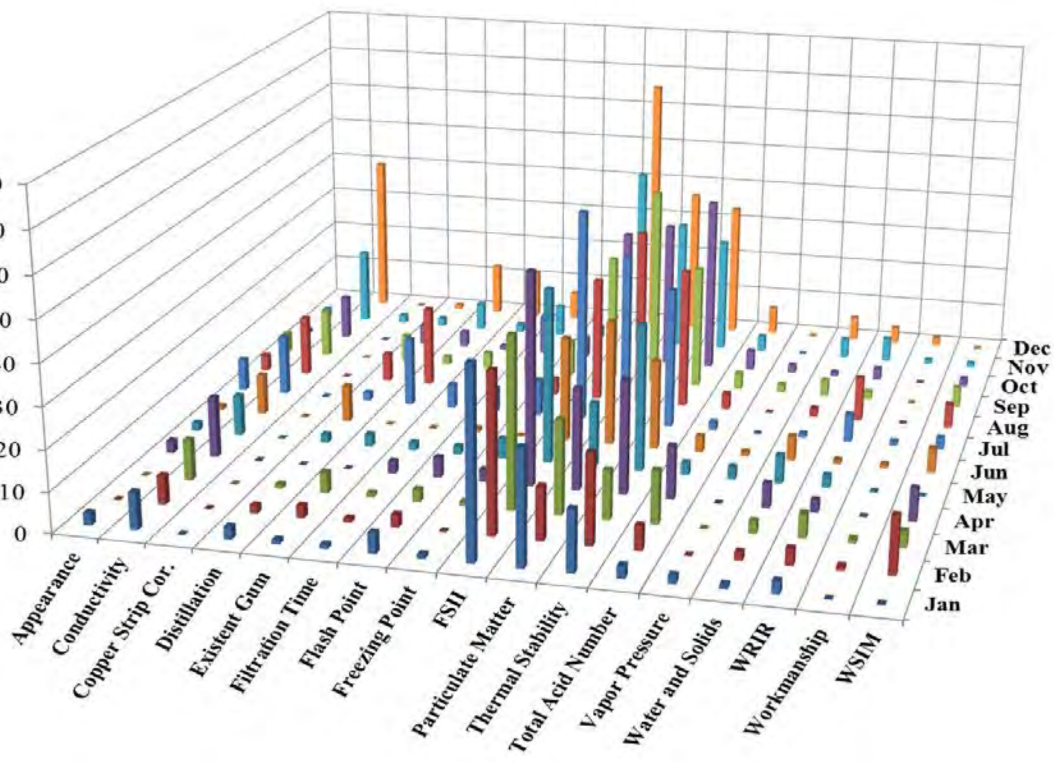

Figure 2. Monthly QA test failures recorded in AFTAT database from 2007 to April, 2015.

Contamination case studies from the Army, Navy, and Air Force were examined as well as records of laboratory test on unknown contaminants. The majority of "unknown" contamination occurrences were the result of finding excess particulate matter, or discolored water in issue or receipt filter separators as well as, (to a lesser degree), FSII and Thermal Stability. Typically, locations reporting contaminated fuel have returned to providing clean fuel quickly, however, in many cases the source of contamination was not documented.

On-Site Visits.

During July and August 2014 four diverse military installations; Location A, Location B, Ft Rucker AHB, and Location D; were visited to see firsthand how established guidance is translated into action by line personnel. QA procedures across publications are well harmonized with MIL-STD 3004D, TM 4-43.31, TO 42B-1-1, NAVAIR 00-80T-109, ClNCLANTFLTINST/CINCPACFLTINST 4026.1, providing primary guidance across the DOD. These visits as well as observations made during site visits on previous programs have revealed that there are a variety of issues that have to be dealt with locally to avoid procedures that allow contamination to build up to the point that it causes a real problem. These observations are filed with DLA Energy DQ Research and Development.

QA field issues observed during site visits:

- Bulk storage "all level" samples were taken from the outlet side of the filter-separator while recirculating fuel from storage tanks. Sample should have been taken from inlet side of filter-separator to measure quality of bulk fuel.
- Broken threaded end cap on filter submitted for analysis indicates proper torqueing procedure may not have been followed.
- Personnel operating a fuel facility had no procedure for checking fuel – water level in storage tanks.
- Personnel sampling a bulk storage tank used an uncontrolled bottle sampler for all level samples.
- Initial shipments of fuel from DFSPs lack sufficient additives to pass QA. Frequently second shipment is adequate; whether injectors need to warm up or operators miss correct set point is unknown.
- Where filters are frequently replaced, separators were given only a cursory exam and not removed for examination.

Task 3: Contact component manufactures for material list.

Fuel wetted material list was obtained from: AFCESA HRJ Fuel Study (Investigative Study to Determine Effects of Hydro-Treated Renewable JP-8 Jet Fuel Blend in Existing Fuels Infrastructure). Attachment 2 lists the fuel wetted materials as well as material and alloy composition.

Task 4: Contact coating manufactures for material composition and application process.

Authorized coatings for fuel storage tanks are described in MIL-PRF-23236D and listed in QPL-23236. The original Mil-P-23236(SHIPS) (14 pages), dated June of 1962 along with its subsequent revisions ran concurrently with MIL-C-4556 until November of 2011 when MIL-PRF-23236D superseded MIL-PRF-4556F and effectively became the sole performance specification for epoxy coatings for shipboard tanks and other surfaces.

The Unified Facilities Guide Specifications sections 09 97 13.15 and 09 97 13.17 detail coating specifications and formulations for newly constructed fuel storage tanks. Detailed descriptions of minimum qualifications for applicator personnel, quality control measurements as well as application procedures are covered. Sample recipes are provided, with sources, to allow on site coating blending.

UFGS-33 52 80 Covers external and internal coatings for pipelines. The guide covers process and quality control of coating application in detail, while requiring interior coatings for jet fuel pipelines is of the Fusion-Bonded Epoxy type and the manufacturer's statement of compatibility with jet fuel. Without a list of approved formulations it will be difficult to provide guidance to aid laboratory identification of suspect particles resulting from pipeline coating failures.

MSDS's were downloaded for all the fuel qualified coatings in the current QPL-23236D which have been certified for fuel tank use. Separate listings were constructed of the purely hydrocarbon components and metallic or mineral components. Where possible trade names and common names have been replaced with proper chemical names. The most likely indication of coating degradation particles is the presence of metal or mineral topcoat additives. Approved products and metal/mineral contents are contained in Attachment 3.

The issue of using coating composition to identify failed coating particles hinges on 3 common methods of analysis, LM (light microscopy), SEM-EDX/XRF (Scanning Electron Microscopy - Energy Dispersive Spectroscopy / X-Ray Fluorescence), and FTIR (Fourier Transform Infrared Spectroscopy). Frequently LM can identify larger particles as coatings however, if the particles are too small to be identified positively by microscopic evaluation there remains only chemical composition. SEM-EDX / XRF is used to identify elemental composition and can cover an area on the order of 1000 µm2 down to single µm sized particles. Actual limits of detection and spatial resolution are heavily dependent on the particular technique used. Approximate agreement with typical coating components along with particle morphology may provide sufficient information for positive identification. FTIR is sensitive to chemical bonds and is used mostly to identify organic compounds by matching instrument response to library records, (micro FTIR can be used on single particles larger than several microns).

Task 5: Analyze additional fuel and water-bottom samples for background content.

Background metals content of jet fuels has been the subject of several studies. [ii, iii] In general, metal content greater than 100 ppm is not normal. Most metals are below detection limits or below 50 ppb when measured by ICP-OES, (Inductively Coupled Plasma-Optical Emission Spectroscopy). Measuring metal content of 10 ppb or lower concentration requires extreme measures to avoid contamination after the sample is acquired and is not a realistic goal.

Microscopic analysis of 'Laboratory Filtration" and "Inline Filtration" filters.

A total of 29 filters were collected from inline and laboratory filtration quality control testing operations at the four bases visited. Samples were taken from a range of fuel system sample collection points and examined by light microscopy, SEM and where particles were evident, XRF. Operational conditions ranged from no issues to continual filtration plugging and were meant to span the range of real field fuel quality issues. Attachment 4 contains analysis results and representative photo micrographs of the range of 'none' to 'failing' particle contamination levels found on lab filtration test filters and inline filtration filters. The usefulness of various laboratory techniques and reporting methods to field operators is addressed under Task 6.

While the majority of filters represent samples of clean fuel, filters 25 through 27 represent filtration test results from a continuing issue with pipeline receipts at Location D. Analysis of particles from the highest particulate filter showed measurable amounts of sodium, chlorine, and potassium which may have been known to accelerate rust production. An additional point of interest is that this location has had a past history of caustic material being received through the pipeline.

Bulk fuel filter analysis

A filter/separator element was received from Location D for analysis of abnormal contaminant levels and a micronic bulk filter from Location B-2 bulk storage. Normal filter element lifetime for Location D is on the order of 1 month, or less, and elements are replaced when the pressure drop hits approximately 20 psig. Fuel receipt is via pipeline from a contractor run DFSP facility where FSII is injected. Location D has had problems with particulate

contamination in the past which was attributed to poor FSII mixing in the pipeline. The geometry of the mixing region has since been changed to improve FSII distribution, however, particulate loads were still high in pipeline receipts when Location D was visited. Since 2014, fuel deliveries have been made by truck.

A filter/separator element from Location B-2, and a filter/separator element from Location D were sectioned for analysis. Two approaches were used to obtain representative samples of filter material.

End caps were removed from one filter with a manual "hacksaw". The spiral wound metal perforated tube had a tendency to grab and twist the blade making it necessary to hold the filter as firmly as possible. Without a special fixture to immobilize the filter while removing the end caps the outer filtration layers are continuously twisted and compressed. Removing the outer filtration layers before cutting the metal core is quite tedious but is the preferred alternative. All filtration layers were sequentially removed to allow cutting 3 rectangular samples from each end and the middle. End samples were subject to additional contamination from the vigorous sawing action needed to remove the end caps.

The second filter separator was treated somewhat differently. A metal cutting band saw was used to remove the end caps. This did not eliminate the metal particles but it did eliminate the vigorous twisting and squeezing necessary to stabilize the filter during hand sawing. Once the ends were removed, each layer was sequentially cut from one end to the other and flattened on the table. A continuous strip was then cut from the material so that the sample would form a complete circumferential band. Samples were cut from each end and the center. Strips were cut from the center pleated material with a razor blade while keeping the pleats intact, (without stretching). All samples were wrapped in aluminum foil and bagged in Ziploc™ bags for later analysis. Photographs and microphotographs of the filter material can be seen in Attachment 4.

Filter Separator Evaluation Notes:

- Fuel flow through the metal tube perforations has concentrated particulates in the area of the holes.
- The filter from Location B had performed for approx. 3 years before normal replacement and had very dark markings from fuel flowing through the perforations.
- The filter from Location D was in service for a very short time before high delta pressure across the filter separator unit necessitated replacement, yet, the layer outside of the metal tube showed little coloration except at the very end of the filter. Separating pleated filter layers at the center of the filter revealed a red "paste like" coating material between the first and second layers. (There was also a significant amount of red powder adhering to the inside surface of the end caps that was not visually present in the filter material.)
- Removing end caps by using a metal saw generates metal particles of various sizes.

Task 6: Field Investigation Challenges

The main causes of fuel contamination are commingling with other petroleum products and contamination with water; solids and microbiological growth[iv]. If fuel adulteration is suspected, the entire suspect volume must be quarantined until the type and concentration of comingled material is determined.[v,vi,vii] Clogged filters or excessive water bottoms represent issues that must be dealt with through improved housekeeping and are not in themselves a problem. However, if filters show evidence of allowing contaminants or water to continue downstream, or if the water bottoms contain evidence of corrosion products, surfactants, or microbial contamination, then the source must be found and dealt with.

The fundamental requirement for any successful solution is a proper field sample. Samples that are improperly acquired, ill timed, or poorly processed are not suitable for the most sensitive laboratory tests. Because improperly taken samples can completely invalidate a test, only trained and experienced personnel should be assigned to sample the products. This cannot

be overstressed: No amount of laboratory work gives reliable data on a product if the sample is not a true representation of that product.[viii] Fuel samples used to determine if the product is degraded or adulterated should be taken per established product sampling guidelines.[ix]
Area fuel laboratories and contract laboratories occupy a central position in the process of contaminant investigations. Occasionally their analysis of unknown contaminants fails to provide any meaningful guidance apart from normal Quality Assurance (QA) test results. How can an extensive array of cutting edge instrumentation along with decades of experience fail in its stated goal?

- Poorly communicated contamination description.
- Samples do not reflect initial contamination description.
- No information concerning the location of contamination within the fuel system.
- Contamination resulting from intermittent flow may be absent from standard fuel sampling locations.
- Local fuel team has no written guidance on capturing fuel and water sump samples for analysis.
- No **single** local person is tasked with conducting the investigation.

Initial Contaminant Description

The initial report of contamination should include evidence of unknown sump material, failed QA tests, or filter evidence of unusual fouling. Pictures or email without physical evidence cannot be the basis of any definitive contaminant identification.

Non-representative Samples

Standard QA fuel samples can be completely, (or nearly), free of a contaminant that has been found in a sump or plugged filter. Polar contaminants or water soluble materials may collect in measurable quantities only in storage tank water bottoms or filter separator sumps. In order to determine the components in a sump sample, the sump material must be captured for analysis.

Contamination Location and Provenance

In order for Laboratory personnel to quickly identify unknown contaminants, they must know what they are looking for. With modern instrumentation it is possible to detect unbelievably low levels of foreign materials in jet fuels. For the most part, these materials will be removed by filtration or water separation and cause no further problems. Without a comprehensive understanding of where the contamination was discovered it is not possible to know which materials are out of place and concentrated enough to cause problems.

Intermittent Contaminant Flow

Typically a problem with contaminated water bottoms, the material may not appear at all in normal fuel samples except under unusually high flow conditions or after uncommon tank stirring. In these cases, submitting clean fuel samples will not help to identify where the slurry or gelatinous material in a filter separator sump came from. Polar contamination should point toward collecting samples from all upstream sumps and tank bottoms.

Local Focal Point is Absent

Unless responsibility for leading a contamination investigation rests with a single local individual, it is unreasonable to expect proper samples and efficient information transfer to the investigation team members. Attachment 5 illustrates a possible application of "Crisis Management" techniques to control the process of evaluating and mitigating occurrences of serious QA testing failures.

Task 6: Laboratory Challenges

The first step in identifying unknown sample components is the visual sample description including general appearance, smell and phase quantification. Presence of a water phase, particulates, microbial evidence, discoloration, and smell all suggest a different mix of analysis. Actual failed hardware will require extra steps to obtain samples for analysis, such as solvent extraction and sectioning for microscopic examination. Attachment 6 lists typical instrumentation found in laboratories suitable for unknown contaminant analysis along with the type of information they generate. Concurrent with the initial sample evaluation, laboratory personnel should receive information describing the affected fuel system, recent maintenance, recent QA test results, and fuel deliveries.

Contaminants that are water soluble, solids, or microbes that reside at the fuel – water interface may not be evident in bulk fuel samples. These contaminants are moved through the fuel system by turbulent flow from their point of origin. Without a rigorous water removal program the first indication of water /solids / microbial contamination will be seen in the filter separators. Bottom samples and separator sump samples are needed to determine the extent of the contamination and operability of the filter separators. A single sample gives an extremely limited view of system cleanliness. As a bare minimum, sump samples should be taken from any storage tank and F/S unit immediately upstream and downstream of the contamination discovery. Attachment 7 illustrates two protocols for taking special samples after a QA failure is verified. These samples should be taken immediately, before any remediation process is started since they are likely to contain the evidence of contamination extent. Attachment 8 lists the effects of typical contaminants on QA tests normally run in the laboratory.

Visual evidence of a 'Rag Layer' between fuel – water phases indicates fungal / bacterial contamination with probability of contaminated fuel passed downstream. Microbial contaminated water-bottoms will become acidic as the culture ages, resulting in increased corrosion products to plug filters. Microbial biofilms tend to disarm coalescers while entrained spoors colonize the filtration surface on F/S elements. Attachment 9 contains the rational behind microbial testing and some of the pitfalls in interpreting results from commercial test kits.

The analysis report should depend on the "desired outcome". Reporting needed by field personnel to 'fix' local deficiencies should be detailed enough to eliminate the majority of infrastructure from suspicion and point toward likely contamination sources. If the laboratory report is necessary to highlight a major system deficiency or document a failure path to an AC incident, AC grounding, or fuel re-grade it should also include a high-level summary suitable for briefing personnel who have limited understanding of fuel issues.

Concerns expressed by laboratory personnel include lack of communication between contamination team members. Team members submit samples without providing sufficient information to guide analysis. For some samples, communication may need to be ongoing throughout analysis to avoid unproductive analysis.

Personnel would benefit from associating with other lab professionals to share information and techniques that have been useful in prior contamination studies. While a formal conference with organized presentations might be the preferred, an online user group could perhaps perform the same function with faster responses and lower cost.

Presentations

May 5, 2015: Presentations at the CRC Aviation meeting in Alexandria, VA. "Best Practice for Contamination Testing"; Fuel Handing and Contamination Group session.
Oct. 4-8, 2015: Presentation at IASH 2015, Charleston, SC. Best Practices for Jet Fuel Contamination Response.

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[i] TO 42B-1-1 Rev 10 Chg 1 19 Nov. 2012, chapter: 4.4.3 General Sampling Procedures.

[ii] O.J. Hadaller, J.M. Johnson; *World Fuel Sampling Program, (appendix D)*; CRC Report No. 647, 2006; Coordinating Research Council Inc, Alpharetta, GA,

[iii] J.T. Edwards, Ph.D., AFRL; Tri-Service Jet Fuel Characterization for DOD Applications, SwRI Project No 08.17149.36.100; 2014.

[iv] MIL-STD-3004D, 5.11.3

[v] MIl-STD-3004D

[vi] CINCLANTFLTINST/CINCPACFLTINST 4026.1; NAVAIR 00-80T-109

[vii] TO 42B-1-1

[viii] Mil-STD-3004D, 4.2.1.2

[ix] Mil-STD-3004D; ANSI Z1.4; API MPMS; ASTM D 4057; ASTM D4177

Attachment 1

Literature References for Jet Fuel Quality Control Procedures

Army Documents

AR 710-2; Supply Policy Below the National Level
Sect. 4, chapter 29: "Establish effective petroleum quality surveillance and technical assistance programs.
C-4, pp 260- : Quality Surveillance Program.
Reference to 3004 for sampling intervals and types of samples. Fuel problems will be reported to USAPC.

FM 10-67; Petroleum Supply in Theaters of Operations.
Directions for field personnel to receive, store and issue fuel to friendly vehicles. Off Spec fuel is not issued.

FM 10-67-1; Concepts and Equipment of Petroleum Operations
Chapter 3, Section 3: Sampling. Reference to ASTM 4057 for specific information on sampling procedures.
Chapter 3, Section 4: Petroleum Quality Maintenance. Very general guidance on preventing contamination.
Chapter 20: Filter separator operation and maintenance.

FTL 11-02; Filter Effectiveness Program – Millipore Use
This letter urges all units to perform monthly filter effectiveness testing using the Millipore monitor and sending it to area laboratory instead of sending a gallon fuel sample.

TM 4-43.31; Petroleum Laboratory Testing And Operations
"6-10. The testing of DLA-owned and Army owned petroleum products in the developed theater in peacetime is described in MIL-HDBK-200." (MIL-HDBK-200 replaced by MIL-STD-3004D)
3-51. Solid contamination consists of both suspended particles and sediment that may come from any of the following sources: sand or dirt, dust from the air, metal from repair or wear, plasticizers from hose liners, lint, or black (magnetic) and red (non-magnetic) iron oxides. The size of the particles and the amount are of critical importance because of small clearances in the aircraft and diesel equipment. Fine particles are less than 10 microns in size. A micron is 0.0001 millimeter, or 1/25.400 of an inch. These particles are not ordinarily visible to the unaided eye. Thus, a fuel without visible solids is not necessarily acceptable. Fine particles less than 5 microns in size cannot be removed readily by settling. Coarse particles are 10 microns or larger, and these can be detected visually. Such contamination settles out fairly easily, and all of it can be separated by adequate filtration. For additional information on contamination, see Table 3-1.
3-52. Water may be present in the dissolved state or in the free (emulsified) state. Water dissolved in fuel is similar to moisture in the atmosphere. Dissolved water cannot be detected visually, nor can it be removed by filter/separators. Small quantities of water do not harm the fuel if the water remains a solution.
However, it separates readily when the fuel cools to a temperature lower than that at which the water went into the solution. Dissolved water becomes free water when it separates from the fuel.

3-53. Free Water. Free water may appear in the form of a cloud or haze. It may also appear as an emulsion. It may appear in the form of droplets clinging to the side of containers. Free water is undesirable because it causes icing, corrosion, and malfunctioning of aircraft accessories. Free water in gasoline, diesel fuel, and turbine fuel can be removed easily by settling and by adequate filter/separators.

Pamphlet 385–40; Army Accident Investigations and Reporting
Directions for documenting accidents involving Army equipment and or personnel.

Pamphlet 710–2–1; Department of the Army Inventory Management Using Unit Supply System
Directions for documenting supply chain management of Army materiel.
Chapter 12: Petroleum Management. Covers sampling of bulk storage and filter effectiveness sample procedures.

Navy Documents:

ClNCLANTFLTINST/CINCPACFLTINST 4026.1; Fuel Management Afloat Manual
Chapter 4: Quality Surveillance.
Sections 4-1 thru 4-4 Cover sampling requirements, equipment, and procedures as well as shipboard testing with ASTM references for JP-5. Types of contamination are described as well as the operational problems caused by contamination. Also covered are general types of mitigation process for contaminated or degraded fuel. Contamination that is not resolvable thru filtration or water removal requires area laboratory analysis to plan final disposition.

NAVSUPP-558; Fuel Management Ashore
Chapter 4: Quality Surveillance.
QC procedures and standard tests refer to Mil-HDBK-200 (MIL-STD 3004D

NAVAIR 00-80T-109; Aircraft Refueling NATOPS Manual
Chapter 3: Quality Surveillance of Aviation Fuels Aboard Ships. Procedures for routine correlation samples and QC surveillance samples are given. Additional guidance is given on laboratory equipment needed for shipboard testing, test methods and interpretation. Guidelines for requesting regional laboratory services and their addresses is given for cases of suspected contamination. Finally, section 3.8 covers procedures for preventing and controlling contamination. Various appendices contain examples of log sheets, aircraft refueling equipment checklists as well as instructions on safe positioning of refueling equipment.
General contamination guidance: "When off−specification fuel is identified, the refueling truck or other source of fuel will be placed out−of−service pending investigation and other corrective action that may result."
"Any unit that suspects other chemical contamination, deterioration during storage, or other unusual contamination or condition shall send fuel samples to an appropriate fuel laboratory (see Appendix B of MIL−HDBK−844A(AS)) for testing."
"Report and investigate any suspected contamination or any other unusual accumulation of foreign matter. The FO shall be responsible for initiating investigations and formulating corrective actions."

MIL-HDBK-844A (AS); AIRCRAFT REFUELING HANDBOOK FOR NAVY MARINE CORPS AIRCRAFT

6.1.1 Requirement for quality surveillance of aviation fuel. Basic information and minimum requirements pertaining to the quality surveillance of aviation fuels at Navy and Marine Corps air activities are contained in Chapters 3 and 9 of the NATOPS Aircraft Refueling Manual, NAVAIR
1-80 T-109. This chapter provides a brief review of these requirements with amplifying information.

NAVFAC MO-230; Maintenance and Operation of Petroleum Fuel Facilities

This manual presents general guidelines and, where possible, specific procedures to be followed in the maintenance of petroleum handling facilities. It covers both short-term maintenance routines and longer term, heavier maintenance that can be carried out by regular operating personnel or maintenance technicians. Whenever fuel quality monitor elements require replacement, filters, filter/separators, and strainers located upstream from the monitor should be inspected for contamination. If contamination is found, its source must be identified and stopped."

<u>Air Force Documents:</u>

To 42B-1-1 REV 10 CHG 1 19 Nov, 12; Quality Control of Fuels and Lubricants

"Sources and types of contamination are identified to aid base personnel in preventing quality degradation."

"Solid contamination which cannot be identified should be forwarded to the area laboratory at Location A, OH addressed to the attention of the Technical Division."

"When a retest confirms a failure for solids or free water, conduct an investigation to determine the cause. It may be necessary to sample upstream of the filter separator to locate the source of the contaminant. Contact AFPA Technical Division and Current Operations Division for additional guidance."

"When contamination downstream of aircraft servicing filter separators exceeds 0.5 mg/L or when free water is greater than 10 ppm, the servicing equipment shall be taken out of service and investigative action performed."

"Microscopic analysis of the solids can provide information as to contamination sources and is therefore recommended as a procedure to follow when limits are exceeded."

<u>Department of Defense Documents:</u>

MIL-DTL-83133H; Jet Fuel JP specification

Contains specification limits for legacy JP-8 and "renewable" JP-8 blends. Also contains description of filtration testing for particulate and gum contamination.

MIL-HDBK-510-1A; AEROSPACE FUELS CERTIFICATION (DOD)

This military handbook provides guidance for evaluating and certifying aviation fuels and aviation fuel additives and is consistent with MIL-HDBK-516, Airworthiness Certification Criteria; and MIL-HDBK-514, Operational Safety, Suitability, & Effectiveness for the Aeronautical Enterprise.

MIL-DTL-83133H w/ AMENDMENT 2; DETAIL SPECIFICATION: TURBINE FUEL, AVIATION, KEROSENE TYPE, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37) (DOD)

Specification limits and testing methods are detailed or referenced.

MIL-STD-1518C; DOD Standard Practice Storage, Handling, and Servicing Of Aviation Fuels, Lubricating Oils, And Hydraulic Fluids at Contractor Facilities. (DOD)

"5.4.2 Contractor sampling requirements. The contractor is responsible for performing all sampling and testing required in table I. The validity of test results is greatly influenced by sampling procedures. The representative character of the sample is dependent upon the type and cleanliness of the sample container, the sampling operation, and the purpose for which the sample is being taken. The basic principle of any sampling procedure is to obtain a sample or composite of several samples in such a manner that the sample to be submitted for testing will be truly representative of the product."

MIL-STD-3004D w/Change 1; Quality Assurance / Surveillance for Fuels, Lubricants and Related Products. (DOD)

"Suspected contamination of petroleum products shall be confirmed by laboratory tests." "When product does not meet specification limits, the facility having physical possession of the product shall provide pertinent details to DLA-ENERGY-QA for bulk products..."

"When Service-owned product does not meet intra-Governmental receipt limits set forth in this Standard; they will contact the using Service's technical office (see 5.13.3) for a decision concerning its use or disposition."

"5.13.6.1 Determining factors. The following factors shall be carefully considered before reclamation is recommended:

a. Contaminating agents present and source of contaminants.
b. Degree of contamination.
c. Probable end use of petroleum product in present condition with consideration given to laboratory analysis, purchase specification, established intra-Governmental receipt limits and safety factors.
d. Feasibility of removing or nullifying undesirable effects of contaminants so the petroleum product may be used.
e. Actual location and quantities of off-specification or contaminated petroleum product.
f. Probable need for reclaimed petroleum product.
g. Availability of time, materials, equipment and labor necessary to reclaim the off-specification or contaminated product.

5.13.7 Reclamation techniques"

MIL-HDBK-114A; Fuels Mobility User Handbook (DOD)

"-provides basic information design criteria for the identification and selection of hydrocarbon fuels and alternative products."

MIL-DTL-24441D(SH); General Specification for Paint, Epoxy-Polyamide.

This specification covers a series of two component epoxy-polyamide paints designed to protect surfaces from environmental attack.

MIL-DTL-24441/29B (SH); Detail Spec Sheet for Epoxy-Polyamide, Green Primer, Formula 150, Type IV
Tables list components of Epoxy tank coatings to be prepared by the coating vendor. Several components are generic and in some cases component concentration is variable according to users' requirements.

MIL-DTL-24441/31B (SH); Detail Spec Sheet for Epoxy-Polyamide, White, Formula 152, Type IV
Tables list components of Epoxy tank coatings to be prepared by the coating vendor. Several components are generic and in some cases component concentration is variable according to users requirements.

Civilian Documents:

UFC 3-460-03; 21 Jan. 2003 (DOD)
"1.1.3. This manual establishes the minimum maintenance standards for fueling systems and applies to all active installations. If the installation is in an inactive or surplus status, reduce maintenance standards to a point consistent with the anticipated mission. If existing Department of Defense (DOD) directives are available with clearly outlined maintenance guidance, you will be referred to those publications. This will standardize maintenance requirements between the fuel system operators and the liquid fuels maintenance personnel and reduce revisions and administrative requirements."

UFC 3-460-01; 16 August 2010 (DOD)
"This Unified Facilities Criteria, UFC 3-460-01, contains general criteria and standard procedures for the design and construction of military land-based facilities which receive, store, distribute, or dispense liquid fuels. It is also applicable to the handling of liquefied petroleum gases (LPG) and compressed natural gas (CNG). It provides guidance on the rehabilitation, deactivation, or closure of fueling facilities. Support facilities are also included. Facility Plate 001 provides assistance in identifying UFC chapter numbers for specific fueling components."

UFGS-09 97 13-15; Unified Facilities Guide Specification for Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks.
Tables list components of Navy formula 150 Epoxy Type IV, Epoxy Primer Coat; Navy formula 152 Type IV Epoxy Intermediate Coat; and Fluoropolyurethane Topcoat along with application directions and QC procedures to insure optimum coating performance.

UFGS-09 97 13-17; Unified Facilities Guide Specification for Three Coat Epoxy Interior Coating of Welded Steel Petroleum Fuel Tanks. (AF version of UFGS-09 97 13-15)
Tables list components of Navy formula 150 Epoxy Type IV, Epoxy Primer Coat; Navy formula 152 Type IV Epoxy Intermediate Coat along with application directions and QC procedures to insure optimum coating performance.

STANAG 1110 DPP (EDITION 10); Allowable Deterioration Limits For NATO Armed Forces Fuels, Lubricants And Associated Products.
"The purpose of this STANAG is to define the extent to which these changes are acceptable so that the product may still be used for its intended purpose and to retain the NATO Code Number as defined in STANAG 3149 Annex A, paragraphs 5 and 6."

STANAG 3149 (EDITION 10); - Minimum Quality Surveillance For Fuels
"The purpose of this STANAG is to provide a set of agreed guidelines, to be used as a minimum by participating nations in the handling and quality assurance of bulk and packed fuels."

STANAG 3609 OPP (EDITION 5); - Standards for Maintenance of Fixed Aviation Fuel Receipt, Storage and Dispensing Systems
"The aim of this agreement is to establish minimum maintenance standards for fixed Jet Fuel Storage Installations (JFSIs) used by NATO nations."

STANAG 7063 DPP (Edition 2); -Methods of Detection and Treatment of Fuels Contaminated By Micro-Organisms
Approved detection kits and approved microbicides for various NATO signatories.

AFLP – 3747 (STANAG); Guide Specifications (Minimum Quality Standards) For Aviation Turbine Fuels (F-24, F-27, F-34, F-35, F-37, F-40 AND F-44)
"This Guide Specification represents the minimum quality standards acceptable under the appropriate NATO Code Numbers."

Jig 1; Guidelines for Aviation Fuel Quality Control and Operating Procedures for Joint Into-Plane Fueling Services.
For microbial testing: " An investigation into the source of the contamination of airport furl storage shall take place and this shall include on-site assay testing of the upstream supply locations ()."

Jig 2; Guidelines for Aviation Fuel Quality Control and Operating Procedures for Joint Into-Plane Fueling Services
"If abnormal quantities of free water or sediment are found, or if it is not possible to obtain a clear and bright sample which provides a satisfactory visual check, the vehicle shall be withdrawn from service and an investigation shall be carried out immediately to determine the source of the contamination."

Jig 3; Guidelines For Aviation Fuel Quality Control And Operating Procedures For Jointly Operated Supply And Distribution Facilities.
"If results are confirmed, (microbiological testing), seek guidance."

EI/JIG Standard 1530; Quality assurance requirements for the manufacture, storage and distribution of aviation fuels to airports.
"EI/JIG 1530 is intended to provide a standard to assist in the maintenance of aviation fuel quality, from its point of manufacture to delivery to airports... It is not intended to be a substitute for a site-specific operating and fuel quality control manual."
Contains an extensive list of standard methods and standard specification documents and will replace JIG 3 at a later date.

ATA Specification 103 Standards for Jet Fuel Quality Control;
"This standard identifies commonly recognized industry inspection procedures and safety checks of jet fuel storage and distribution facilities at airports that will help minimize introduction of contaminated or unacceptable jet fuel from being delivered to airline aircraft."
"Remove tank from service if unable to obtain clean, dry fuel. Report unusual contamination to aircraft operators if it is anticipated that such contamination may impact aircraft operations."

IATA Guidance Material for Investigating and Categorizing of Engine Fuel Filter Blockages, 1st Edition;
"This standard procedure describes the IATA Technical Fuel Group agreed standard method for the removal and analysis of the composition and categorization of the debris from engine fuel filters." Includes step by step methods of filter deconstruction and particulate recovery as well as non-particulate contaminant.

ANSI/ASQ Z1.4-2008; Sampling Procedures and Tables For Inspection By Attributes
"The purpose of this standard is, through the economic and psychological pressure of lot non-acceptance, to induce a supplier to maintain a process average at least as good as the specified AQL while at the same time providing an upper limit on the consideration of the consumer's risk of accepting occasional poor lots. The standard is not intended as a procedure for estimating lot quality or for segregating lots."

ASTM - D4057 – 12; **Standard Practice for Manual Sampling of Petroleum and Petroleum Products**
"This version will provide guidance on manual sampling terminology, concepts, equipment, containers, procedures, and will provide some specific guidance related to particular products and tests. The type and size of the sample obtained, and the handling method, will depend on the purpose for which it was taken. Refer to the test method for any specific sampling and handling requirements up to the point of testing."

ASTM - D7464; Standard Practice for Manual Sampling of Liquid Fuels, Associated Materials and Fuel System Components for Microbiological Testing
"4.1.1 Fuel and fuel-associated bottom-water samples intended for microbiological testing are collected similarly to conventional samples as described in Practice D4057, however specific measures are added to reduce the risk of sample contamination."

ASTM – D6469-42; Standard Guide for Microbial Contamination in Fuels and Fuel Systems
"This guide provides information addressing the conditions that lead to fuel microbial contamination and biodegradation and the general characteristics of and strategies for controlling microbial contamination. More detailed information may be found in the IP Guidelines and in ASTM Manual 47." Extensive references are provided for all aspects of sampling and analyzing microbial contaminants.

ASTM-D5452; Std. Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration
Filtration method for determining particulate load in fuel sample.

Manual 1 ASTM - MNL1-EB-DL ASTM 4690; Significance of Tests for Petroleum Products
Section 2: Aviation Fuels.
History of aviation fuel development and current specifications and permitted additives. Limited discussion on contamination.
Section 9: Methods for Assessing Stability and Cleanliness of Liquid Fuels.
Extensive overview of types of contaminants typically found in fuel, the affect of contaminants on fuel performance, ASTM methods for quantification of contaminants, sampling procedures and methods to support the various tests.
Section 17: Sampling Techniques

Covers the procedures and equipment necessary to obtain a representative sample on which quantitative and qualitative analyses can be performed in Section I: Manual Sampling, and Section II: Automatic Sampling

Manual 5 ASTM – MNL5-EB-DL22517; Aviation Fuel Quality Control Procedures: 4th Edition

"This manual provides guidance material on common procedures that are used to assess and protect aviation fuel quality. In many cases, the field procedure or test method listed herein is a simplified version of the corresponding ASTM method or standard practice. It should be emphasized that the formal ASTM standard method supersedes the instructions given in this publication. "

Manual 47 ASTM –MNL47; Fuel and Fuel System Microbiology

Microbiological principles underlying fuel and fuel system biodeterioration. This collection of documents includes detailed instructions on: Sample collection and handling, recommendations for disinfecting and removing microbial contamination from fuels and fuel systems, and a variety of diagnostic tests.

ICAO 9977; Manual on Civil Aviation Jet Fuel Supply

"A primary purpose is to mitigate the threats to aviation fuel quality and to ensure the safe delivery of fuel into aircraft fuel tanks (into-plane). The various controls and procedures reflect a philosophy of product testing, traceability and segregation to prevent contamination and to ensure that the fuel is on-specification at point of delivery to aircraft."
Appropriate industry documents are referenced for detailed instruction in sampling, testing and documenting quality control of fuel stocks.

Cleanliness and Contamination Methods

ASTM	IP	Title
D381	**131**	Gum Content in Fuels by Jet Evaporation
D1094		Water Reaction of Aviation Fuels
D2068		Filter Plugging Tendency of Distillate Fuel Oils
D2276	**216**	Particulate Contaminant in Aviation Fuel by Line Sampling
D3240		Undissolved Water in Aviation Turbine Fuels
D3948		Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer
D4176		Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
D4740		Cleanliness and Compatibility of Residual Fuels by Spot Test
D4860		Free Water and Particulate Contamination in Mid-Distillate Fuels (Clear and Bright Numerical Rating)
D5452	**423**	Particulate Contamination in Aviation Fuels by Laboratory Filtration
D6217	**415**	Particulate Contamination in Middle Distillate Fuels by Laboratory Filtration
D6426		Determining Filterability of Distillate Fuel Oils
D6469		Microbial Contamination in Fuels and Fuel Systems
D6728		Determination of Contaminants in Gas Turbine and Diesel Engine Fuel by Rotating Disc Electrode Atomic Emission Spectrometry
D6824		Determining Filterability of Aviation Turbine Fuel

Sampling Methods

ASTM	Title
D4057	Manual Sampling of Petroleum and Petroleum Products
D4177	Automatic Sampling of Petroleum and Petroleum Products
D4306	Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
D4418	Receipt, Storage, and Handling of Fuels for Gas Turbines

MIL-STD-3004D TABLE XXX

Contamination Tables

TYPE CONTAMINANTS	APPEARANCE	CHARACTERISTICS	EFFECTS ON AI RCRAFT
A. WATER			
(1) Dissolved Water	Not Visible.	Freshwater only. Precipitates out as cloud when fuel is cooled.	None unless precipitated out by cooling of fuel. Can then cause ice to form on low-pressure fuel filters.
(2) Free Water	Light cloud. Heavy cloud. Droplets adhering to sides of bottle. Gross amounts settled in bottom.	Free water may be saltwater or fresh water. Cloudy usually indicates water-in-fuel emulsion.	Icing of fuel systems, usually low-pressure fuel filters; erratic fuel gage readings; gross amounts of water can cause flameouts; saltwater will cause corrosion of fuel system components.
B. SEDIMENT			
(1) Rust	Red or black powder, rouge or grains. May appear as dye-like material in fuel.	Red rust (Fe203) nonmagnetic. Black rust (Fe304) magnetic. Rust generally comprises the major constituent of total sediment.	Will cause sticking, sluggish or general malfunction of fuel controls, flow dividers, pumps, nozzles, etc.
(2) Sand or dust	Crystalline, granular or glasslike.	Usually present and occasionally constitutes major constituent of total sediment.	Will cause sticking, sluggish or general malfunction of fuel controls, flow dividers, pumps, nozzles, etc.
(3) Aluminum or magnesium	White or gray powder or paste.	Sometimes very sticky or gelatinous when wet with water. Normally present and can constitute the major constituent of total sediment.	Will cause sticking, sluggish or general malfunction of fuel controls, flow dividers, pumps, nozzles, etc.
(4) Fibers		A fiber is defined as a particle having a length to diameter ratio of 20 to 1 or more and having a length of 100 microns or more.	Will cause sticking, sluggish or general malfunction of fuel controls, flow dividers, pumps, nozzles, etc.
C. EMULSIONS			
(I) Water in fuel emulsions	Light cloud. Heavy Cloud.	Finely divided drops of water in fuel. Same as free water cloud. Will settle to bottom in minutes, hours, or weeks, depending on nature of emulsion.	Same as free water.
(2) Fuel in water or "inverse" emulsions	Reddish, grayish, or blackish. Sticky material variously described as gelatinous, gummy, or "mayonnaise -like."	Fine divided drops of fuel in water. Contains rust which stabilizes or "firms" the emulsion. Will adhere to most materials normally in contact with fuels. Usually present in "globules" or stringy, fibrous-like material in clear or cloudy fuel. Will stand from days to months without separating. This material contains 50-70% water, a small amount of fine rust, and 30-50% fuel.	Same as free water and sediment, only more drastic. Will quickly cause filter plugging or erratic readings in fuel quantity probes.
D. MICROBIOLOGICAL GROWTH			
	Brown, gray, or black Stringy or fibrous	Usually found with other contaminants in the fuel. Typically found at the fuel water interface but can also form films on the tanks surfaces. Develops only when free water is present.	Fouls fuel quantity probes, sticks flow dividers, and makes fuel controls sluggish.

MIL-STD-3004D TABLE XXXI

Minimum Standards of Filtration and Water Separation for Petroleum Products

PRODUCT	INTO TANK CARS AND TRUCKS 5	INTO DISPENSING UNITS 4	INTO CONTAINERS (PACKAGE)	INTO AIRCRAFT	INTO USING UNIT
Aviation Gasoline Bulk1	150 microns 2 (max) No Visible Water	Filter-Separator 10 ppm by volume water, max.	Filter-Separator 10 ppm by volume water, max.	Filter or Filter-Separator 1 10 ppm by volume Water, max.	
Aviation Gasoline, Packaged 3		Filter-Separator 1 10 ppm by volume Water, max.		Filter or Filter-Separator 1 10 ppm by volume Water, max.	
Aviation Turbine Fuels, Bulk 1	150 microns 2 (max.)	Filter-Separator 1 10 ppm by volume Water, max.	Filter-Separator 1 10 ppm by volume water, max.	Filter-Separator 1 10 ppm by volume Water, max.	
Aviation Turbine Fuels, Packaged 3		Filter-Separator 1 10 ppm by volume Water, max.		Filter-Separator 1 10 ppm by volume Water, max.	
Aircraft Piston Engine Lube Oil, - Bulk	240 microns 2 (max.) No Visible Water	240 microns 2 (max) No Visible Water	240 microns 2 (max.) No Visible Water	240 microns 2 (max) No Visible Water	
Aircraft Piston Engine Lube Oil, Packaged		240 microns 2 (max.) No Visible Water	240 microns 2 (max.) No Visible Water	240 microns 2 (max) No Visible Water	
Aircraft jet Engine Lube Oils, - Packaged		25 microns, absolute (max.) No Visible Water	25 microns, absolute (max.) No Visible Water	10 microns (max) (No Filtration necessary for Hermetically sealed containers)	
Aircraft Hydraulic Fluids - Packaged			(Filtered at time of manufacture), 5 microns, absolute (max)	5 microns, absolute (max) (No filtration necessary for hermetically sealed containers)	
Diesel Fuel MOGAS (applicable for Army only)			Filter-Separator 1 10 ppm by volume Water		Filter-Separator 10 ppm by volume Water

NOTES:

1. Filter-separator in accordance with EI 1581 or MIL-PRF-52308, electronic sensors that provide both a water and solid defense in accordance with EI 1598 and EI 1570, or other approved filter-separator equipment or combinations thereof
2. 150 microns equal 100 mesh; 240 microns equal 60 mesh.
3. All visible water to be stripped or drained from fuel prior to issue.
4. All dispensing units or equipment that issue Aviation Gasoline or Aviation Turbine Fuel directly to aircraft must have a filter separator or electronic sensor installed at point of issue meeting requirements of Note 1.
5. 150 micron equal 100 mesh; 240 micron equal 60 mesh for Lubricating Oils for Tank Cars, Trucks and intermodal Containers.

Attachment 2
Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
AGE Pumps / Dispensers	AGE Pumps / Dispensers	AL				
Ball Valve	Ball	SS	NP			
Ball Valve	Body	CS	SS	AL		
Ball Valve	Packing Gland	SS				
Ball Valve	Retainer	SS				
Ball Valve	Seals and seats	TF				
Ball Valve	Stem	SS				
Ball Valve	Stem Seals	TF				
BASKET STRAINER	Body and Cover	BR	CS	SS		
BASKET STRAINER	Strainer basket	SS				
Bulk Storage Tank Systems	Anti-rotation cable	SS				
Bulk Storage Tank Systems	ATG components	AL	SS			
Bulk Storage Tank Systems	Ball joints	CS	SS			
Bulk Storage Tank Systems	Ball joints, seals	TF				
Bulk Storage Tank Systems	Dielectric bushings / unions	CS	BR	Nylon	VI	
Bulk Storage Tank Systems	Dike liner material	FML	Concrete			
Bulk Storage Tank Systems	Dike liner sealer	Seala				
Bulk Storage Tank Systems	Floating pan	AL				
Bulk Storage Tank Systems	Floating roof	CS	CS	AL		CT
Bulk Storage Tank Systems	Floating roof/pan seals, foam filled	UR				
Bulk Storage Tank Systems	Floating roof/pan seals, wiper type	NE				
Bulk Storage Tank Systems	Gaskets, manway and	FIB				
Bulk Storage Tank Systems	Internal Suction/Diffuser	CS	CT	SS		
Bulk Storage Tank Systems	Ladder and gauge wells	AL	CS	SS		
Bulk Storage Tank Systems	Tank	CS	CS	SS	AL	CT
Bulk Storage Tank Systems	Vapor Recovery Regulators	CI	CS			
Bulk Storage Tank Systems	Vent, Atmosphere (free	AL	CS			
Bulk Storage Tank Systems	Vent, Emergency Housing	AL	CS	SS		
Bulk Storage Tank Systems	Vent, Emergency Pallet	AL	SS			
Bulk Storage Tank Systems	Vent, Emergency Pallet Diaphragm	TF				
Bulk Storage Tank Systems	Vent, Flame Arrestor Grid Assy.	AL	SS			
Bulk Storage Tank Systems	Vent, Flame Arrestor	AL	SS	DI		
Bulk Storage Tank Systems	Vent, Pressure housing	AL	SS	DI		
Bulk Storage Tank Systems	Vent, Pressure Pallet Diaphragm	TF				
Bulk Storage Tank Systems	Vent, Pressure Pallets	AL	SS			
Bulk Storage Tank Systems	Vent, Vacuum housing	AL	SS	DI		

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Bulk Storage Tank Systems	Vent, Vacuum Pallet Diaphragm	TF				
Bulk Storage Tank Systems	Vent, Vacuum Pallets	AL	SS			
Bulk Storage Tank Systems	Vent, Vacuum/Pressure	AL	SS	DI		
Bulk Storage Tank Systems	Vent, Vacuum/Pressure	TF				
Bulk Storage Tank Systems	Vent, Vacuum/Pressure	AL	SS	DI		
Bulk Storage Tank Systems	Water draw-off lines	CS				
Check Valve, Sure Flow type	Body and Flapper	CS	SS			
Check Valve, Sure Flow type	Seat	SS	VI			
Check Valve, Sure Flow type	Spring	IN				
Combination Air Release & Vacuum Breaker Valve	Balance of Internal parts	SS	DE			
Combination Air Release & Vacuum Breaker Valve	Body and Cover	DI	SS	CS		
Combination Air Release & Vacuum Breaker Valve	Float	SS	MO			
Combination Air Release & Vacuum Breaker Valve	Optional lining	EP				
Combination Air Release & Vacuum Breaker Valve	Seals	NR	VI			
DBB Style Plug Valve	Body	CS	SS			
DBB Style Plug Valve	Bonnet/lower plate	CS				
DBB Style Plug Valve	Fyre Pack, w/SS cap	GR				
DBB Style Plug Valve	Fyre Ring	GR				
DBB Style Plug Valve	Gasket	SS	graphite Spiral			
DBB Style Plug Valve	O-rings & slip seals	VI				
DBB Style Plug Valve	Packing gland,	CS				
DBB Style Plug Valve	Plug, fluoropolymer top coat	DI				
DBB Style Plug Valve	Slips, Manganese Phosphate coated	DI	NiR			
Diaphragm Style Control Valve and Components	Cast Stainless Steel 303	SS				
Diaphragm Style Control Valve and Components	Cast Steel ASTM A216-WC	CS				
Diaphragm Style Control Valve and Components	Disc and diaphragm	BN	VI			
Diaphragm Style Control Valve and Components	Main Valve Body and Cover (356-T6)	AL				
Diaphragm Style Control Valve and Components	Nickel Plated Ductile Iron ASTM A-536	DI				

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Diaphragm Style Control Valve and Components	Seat, stem, washers, spring, stem nut, disc guide and retainer, cover bearing	SS	CS			
Diaphragm Style Control Valve and Components	Tubing	CO	SS			
Diaphragm Valve	Base and Mounting Plate	CS				
Diaphragm Valve	Cotter Pins	BR				
Diaphragm Valve	Counter Balance Bracket Assy.	BR				
Diaphragm Valve	Counterweight	CP				
Diaphragm Valve	Float Ball	SS				
Diaphragm Valve	Float Rod Assembly	BR	SS			
Diaphragm Valve	Hex Nut	SS				
Diaphragm Valve	Link Assembly	BR				
Diaphragm Valve	Machine Screw	SS				
Diaphragm Valve	Pilot & Bracket Assembly CF1-Cl	BR	CS	SS		
Diaphragm Valve	Pilot Valve Assembly CF1-	BR	SS	MO		
Differential Control	Adjustment Screw	BR				
Differential Control	Cover	BR				
Differential Control	Diaphragm	Hy				
Differential Control	Diaphragm Washers	BR				
Differential Control	Disc	DE				
Differential Control	Disc Assembly	BR	MO			
Differential Control	Distributor	SS				
Differential Control	Gasket	SR				
Differential Control	Groove Pin	SS				
Differential Control	Lock Pin	SS				
Differential Control	O-Ring	NBR	VI	SR		
Differential Control	Pipe Plug	BR				
Differential Control	Spring	SS				
Differential Control	Spring, Pilot	SS				
Differential Control	Sprint Guides, Upper and Lower	BR				
Differential Control	Stem	MO				
Differential Control	Stem Assembly	BR	SS			
Differential Control	Thrust Washers	BR				
Differential Control	Tubing	CO	SS			
Differential Control	Washer	Oi				
Drybreak Connection	Adapter	AL				
Drybreak Connection	Body's	AL				
Drybreak Connection	Cam arm	AL				

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Drybreak Connection	Center guide poppet	AL				
Drybreak Connection	Coupling with valve	AL				
Drybreak Connection	Poppet	AL				
Drybreak Connection	Poppet Sub-assembly disc	AL				
Drybreak Connection	Seal cylinder	AL				
Drybreak Connection	Springs	AL				
Drybreak Connection	Stem Sub-assembly	AL				
Dry-Break Coupler	Actuator	AL				
Dry-Break Coupler	Ball	SS				
Dry-Break Coupler	Body	AL				
Dry-Break Coupler	Collar, Retaining Ring	SS				
Dry-Break Coupler	Gate	SS				
Dry-Break Coupler	Gate Housing Assembly	AL	NBR			
Dry-Break Coupler	O-ring	NBR				
Dry-Break Coupler	Pivot Pin	AL				
Dry-Break Coupler	Retaining Ring	SS				
Dry-Break Coupler	Rotary Switch Assy.	BZ				
Dry-Break Coupler	Set Screw	SS				
Dry-Break Coupler	Spring	SS				
Dry-Break Coupler	Spring, Actuator	SS				
Dry-Break Coupler	Spring, Collar	AL				
Dry-Break Coupler	Valve Retaining Ring	SS				
Dry-Break Coupler	Washer	SS				
Ejector	Housing	BZ	SS			
Ejector	Inserts	SS				
Filter Meter Pit Valves,	Bearing, Cover	SS				
Filter Meter Pit Valves,	Body	AL				
Filter Meter Pit Valves,	Covers, Bottom and Top	AL				
Filter Meter Pit Valves,	CV Flow Control Housing	BZ	SS			
Filter Meter Pit Valves,	CV Flow Control Other Materials	BZ	MO			
Filter Meter Pit Valves,	CV Flow Control Trim	SS				
Filter Meter Pit Valves,	Diaphragm	SR				
Filter Meter Pit Valves,	Diaphragm Washer	AL				
Filter Meter Pit Valves,	Disc	SR				
Filter Meter Pit Valves,	Disc Guide	SS				
Filter Meter Pit Valves,	Disc Retainer	AL				
Filter Meter Pit Valves,	Ejector Housing	BZ	SS			
Filter Meter Pit Valves,	Gasket	CO				
Filter Meter Pit Valves,	Housing	BZ				
Filter Meter Pit Valves,	Hytrol, body, body plug and cover	BR				

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Filter Meter Pit Valves,	Hytrol, Diaphragm	BN				
Filter Meter Pit Valves,	Hytrol, Diaphragm Washer	BR				
Filter Meter Pit Valves,	Hytrol, Disc Retainer Assy.	BR				
Filter Meter Pit Valves,	Hytrol, spring	SS				
Filter Meter Pit Valves,	Nuts, Jam	BR				
Filter Meter Pit Valves,	Nut-stem Lock	BR				
Filter Meter Pit Valves,	Seat	SS				
Filter Meter Pit Valves,	Spring Guide	BR				
Filter Meter Pit Valves,	Springs	SS				
Filter Meter Pit Valves,	Stem, spring	BR				
Filter Meter Pit Valves,	Stems	SS				
Filter Meter Pit Valves,	Washer	PF				
Flexible Hoses (Pump Flexible Connectors)	Flanges and control rods	CS				
Flexible Hoses (Pump Flexible Connectors)	Multi-ply bellows	SS				
Float Switches	Float Switches	AL	SS			
Float Tester Assembly	O-Ring	BN				
Float Tester Assembly	Plug Guide	AL	SS			
Float Tester Assembly	Spring	SS				
Float Tester Assembly	Stem Riser	AL	SS			
Fuel Hoses	Aircraft fueling hose	NBR				
Fuel Hoses	Hose ends	BR	AL	SS		
Fuel Hoses	unloading hoses	NR				
Fuel Recovery System	Other components	CS	SS	AL		
Fuel Recovery System	Pipe and Fittings	CS	SS			
Fuel Recovery System	Pump, electric	CI				
Fuel Recovery System	Pump, hand, vane	CI				
Fuel Recovery System	Sight glass valves	BZ	CS	SS		
Fuel Recovery System	Sight glass, gaskets	BN				
Fuel Recovery System	Sight glass, glass	glass				
Fuel Recovery System	Tank and Components	SS	AL	CS	CT	
Fueling Nozzles	Ball	SS				
Fueling Nozzles	Body, Inlet	AL				
Fueling Nozzles	Body, Swivel	SS				
Fueling Nozzles	O-ring	NBR				
Fueling Nozzles	O-ring, Inner & Outer Swivel	FL				
Fueling Nozzles	Plug, Ball Race	AL				
Fueling Nozzles	Race Ring	SS				
Fueling Nozzles	Screw, Soc. HD, Cap	SS				
Fueling Nozzles	Slipper Seal	AC				
Fueling Nozzles	Washer	SS				

Distribution Statement A: Approved for public release: distribution unlimited.

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
High Level Control Valves	Arm Extension Nipple	CO	SS			
High Level Control Valves	Disc Assembly	BR	MO			
High Level Control Valves	Distributor	SS				
High Level Control Valves	Float	CO	SS			
High Level Control Valves	Float Arm	BR	SS			
High Level Control Valves	Gasket	SR				
High Level Control Valves	Housing	BR				
High Level Control Valves	Lock Pin	SS				
High Level Control Valves	O-ring Packing	SR				
High Level Control Valves	Screw -RD HD Machine	BR				
High Level Control Valves	Spring	SS				
High Level Control Valves	Stem Assembly	BR	SS			
High Level Control Valves	Thrust Washer	BR	SS			
High Level Shut-Off Valve Trim for Modulating float	Arm Extension Nipple	CO	SS			
High Level Shut-Off Valve Trim for Modulating float	Disc Assembly	BR	MO			
High Level Shut-Off Valve Trim for Modulating float	Distributor	SS				
High Level Shut-Off Valve Trim for Modulating float	Float	CO	SS			
High Level Shut-Off Valve Trim for Modulating float	Float Arm	BR	SS			
High Level Shut-Off Valve Trim for Modulating float	Gasket	SS				
High Level Shut-Off Valve Trim for Modulating float	Housing	BR				
High Level Shut-Off Valve Trim for Modulating float	Lock Pin	SS				
High Level Shut-Off Valve Trim for Modulating float	O-Ring	SR				
High Level Shut-Off Valve Trim for Modulating float	Screws	BR				
High Level Shut-Off Valve Trim for Modulating float	Stem Assembly	BR	SS			
High Level Shut-Off Valve Trim for Modulating float	Thrust Washer	BR	SS			
High Level Shut-Off Valve Trim for Non-Modulating float	Cotter Pins, Brass	BR				

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
High Level Shut-Off Valve Trim for Non-Modulating float	Float Arm	BR	SS			
High Level Shut-Off Valve Trim for Non-Modulating float	Float Ball	CO	SS			
High Level Shut-Off Valve Trim for Non-Modulating float	Float chamber	CI	CS	AL		
High Level Shut-Off Valve Trim for Non-Modulating float	Link Assembly, Brass	BR				
High Level Shut-Off Valve Trim for Non-Modulating float	Pilot valve housing	BZ	SS			
High Level Shut-Off Valve Trim for Non-Modulating float	Seals	BN				
Hose / Connections	Flex Pipe Connections	SS	CS			
Hose / Connections	Gasket	BN				
Hose / Connections	Hose Material	BN				
Hose / Connections	Quick Disconnect (Camlock) Coupler and	AL	BR			
Hose / Connections	Swivels	AL	SS	BR	CS	DI
Hydrant Adapter Valve	Body	BR				
Hydrant Adapter Valve	Disc	FPM				
Hydrant Adapter Valve	Disc, poppet	AL				
Hydrant Adapter Valve	O-Ring	NBR				
Hydrant Adapter Valve	Poppet	AL				
Hydrant Adapter Valve	Retainer Assembly, disc	AL				
Hydrant Adapter Valve	Screw, fillister head	BR				
Hydrant Adapter Valve	Screws	SS				
Hydrant Adapter Valve	Spring	SS				
In-line Centrifugal pump	Case Wearing Rings	BR				
In-line Centrifugal pump	Casing	BR	CI	DI		
In-line Centrifugal pump	Impeller	CS	BR	AL		
In-line Centrifugal pump	Mechanical Seal Assy.	Ni-R	BN	SS		
In-line Centrifugal pump	Shaft	CS	SS			
In-line Centrifugal pump	Sleeve	BR				
Liquid Level gauges and float assemblies	Internal Suction piping and Fill tubes	CS	CS	FRP		CT
Liquid Level gauges and float assemblies	Ladder and gauge wells	CS	CS	FRP		CT
Liquid Level gauges and float assemblies	Liquid Level gauges and float assemblies	SS				
Liquid Level gauges and float	Tank	CS	CS	FRP		CT
Liquid Level Probes	Liquid Level Probes	AL	SS			

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Mechanical Register PD Meter	Auto Air Eliminator/w Check Valve	CS	SS			
Mechanical Register PD Meter	Bearings	CA	TE	Ni-R		
Mechanical Register PD Meter	Chamber Drain	CS	AL	SS		
Mechanical Register PD Meter	Cover Seal O Ring	BN				
Mechanical Register PD Meter	Differential Pressure Gage Assy.	SS	VI	AL	glass	
Mechanical Register PD Meter	Housing	CS	CT			
Mechanical Register PD Meter	Immersion Heater	SS				
Mechanical Register PD Meter	Internal components	AL	Ni-R	SS		
Mechanical Register PD Meter	Manual Water Drain	CS	AL	SS		
Mechanical Register PD Meter	Meter Housing	AL	CI	BR	SS	
Mechanical Register PD Meter	Pilot Control Valve Connection	CS	AL	SS		
Mechanical Register PD Meter	Pressure Gage	BR	BZ	SS	CS	MO
Mechanical Register PD Meter	Pressure Relief Valve, Internal parts	CS	SS			
Mechanical Register PD Meter	Sampling Connection	SS				
Mechanical Register PD Meter	Seal Material	BN	VI	TE		
Mechanical Register PD Meter	Sight Glass and Visi-Flo	CS	BR	SS	DI	
Mechanical Register PD Meter	Spider Plate	AL				
Non-Surge Check Valve	Housing	BZ	AL	DI	CS	SS
Non-Surge Check Valve	Trim	SS	BZ			
Orifice Plate Flange	Orifice Plate	SS				
Orifice Plate Flange	Orifice Plate Holder	CS				
Orifice Plate Flange	Orifice Plate Retaining	SS				
Pilot Assemblies for Diaphragm Control Valves	Excess flow shut-off	BR	SS			
Pilot Assemblies for Diaphragm Control Valves	Float	BR	SS			
Pilot Assemblies for Diaphragm Control Valves	Flow control	BR	SS			
Pilot Assemblies for Diaphragm Control Valves	Reducing control	BR	SS			
Pilot Assemblies for Diaphragm Control Valves	Relief control	BR	SS			
Pilot Assemblies for Diaphragm Control Valves	Solenoid	BR	SS			
Pilot Assemblies for Diaphragm Control Valves	Tubing	CO	SS			
Pipe and Fittings	Aluminum	AL				
Pipe and Fittings	Carbon Steel	CS				

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Pipe and Fittings	Fiber Reinforced Plastic	FRP				
Pipe and Fittings	Gasket Material, paper fiber	PF				
Pipe and Fittings	Interior Epoxy Coated CS per Mil-PRF-4556	CS				
Pipe and Fittings	Nozzles (Single point D-l, D-2 and D-3)	AL	SS	AC	NBR	FL
Pipe and Fittings	Stainless Steel	SS				
Pipe and Fittings	Teflon Sealant for Threaded Connections	TF				
Plug Valve	Body	CS	SS			
Plug Valve	Plug and Stem	CS	SS			
Plug Valve	Sleeve and seal	TF				
Pressure Differential Control	Diaphragm	NBR				
Pressure Differential Control	Diaphragm Washers	BR	AL			
Pressure Differential Control	Disc Assy.	BR	Mo			
Pressure Differential Control	Distributor	SS				
Pressure Differential Control	Gasket	CO				
Pressure Differential Control	Gasket	SR				
Pressure Differential Control	Housing	BR				
Pressure Differential Control	Jam Nut, Stem	BR				
Pressure Differential Control	Lock Washer	BZ				
Pressure Differential Control	O-Ring	SR				
Pressure Differential Control	Pipe Plug	BR				
Pressure Differential Control	Reset Button Assy.	SS				
Pressure Differential Control	Snap Rings	SS				
Pressure Differential Control	Spring Guide, Rack	BR				
Pressure Differential Control	Spring, Pilot	SS				
Pressure Differential Control	Spring, Pilot Actuating	SS				
Pressure Differential Control	Stem	MO				
Pressure Differential Control	Stem Assy.	BR	SS			
Pressure Differential Control	Thrust Washer	BR				
Pressure Reducing Control	Adjusting Screw	BR				
Pressure Reducing Control	Belleville Washer	CS				
Pressure Reducing Control	Body	AL				
Pressure Reducing Control	Body & Seat Assy	BR				
Pressure Reducing Control	Bucking Spring (Required with 2-30 psi)	SS				
Pressure Reducing Control	Cover	AL				
Pressure Reducing Control	Cover	BR				
Pressure Reducing Control	Diaphragm	NBR				
Pressure Reducing Control	Diaphragm	NBR				
Pressure Reducing Control	Diaphragm Washer (lower)	BR				

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Pressure Reducing Control	Diaphragm Washer (upper)	SS				
Pressure Reducing Control	Diaphragm Washers	AL				
Pressure Reducing Control	Disc Retainer Assy	BR	BN			
Pressure Reducing Control	Disc Retainer Assy.	SS				
Pressure Reducing Control	Gasket	FIB				
Pressure Reducing Control	Gasket	NBC				
Pressure Reducing Control	Guide spring	SS				
Pressure Reducing Control	Hex Nut	SS				
Pressure Reducing Control	O-Ring	NBR	FPM			
Pressure Reducing Control	O-Ring	NBR				
Pressure Reducing Control	Plug, 3/8 NPT	BR				
Pressure Reducing Control	Plug, Body	BR				
Pressure Reducing Control	Powertrol Body	AL				
Pressure Reducing Control	Powertrol Body	BR				
Pressure Reducing Control	Seat	SS				
Pressure Reducing Control	Spring	SS				
Pressure Reducing Control	Spring	SS				
Pressure Reducing Control	Spring Guide	SS				
Pressure Reducing Control	Stem	SS				
Pressure Reducing Control	Yoke	BZ				
Pressure Relief Valve, globe valve	Adjustable Spring	SS				
Pressure Relief Valve, globe valve	Body	CS	BR			
Pressure Relief Valve, globe valve	Bonnet	CS	BR			
Pressure Relief Valve, globe valve	Disc	BN				
Pressure Relief Valve, globe valve	Disc Holder	CS	BR			
Pressure Relief Valve, globe valve	O-Ring	BN				
Pressure Relief Valve, globe valve	Spring Washer	CS	BR			
Pressure Vacuum Vent	Body	AL				
Pressure Vacuum Vent	Cap	CS				
Pressure Vacuum Vent	Cap, Gasket	SS				
Pressure Vacuum Vent	Diaphragm Pressure	TF				
Pressure Vacuum Vent	Diaphragm Vacuum	TF				
Pressure Vacuum Vent	Differential Pressure and Pressure	SS				
Pressure Vacuum Vent	Flow Switches	SS				
Pressure Vacuum Vent	Guide Post Pressure	SS				
Pressure Vacuum Vent	Hex Lock Nut	SS				
Pressure Vacuum Vent	Hex Nut	SS				
Pressure Vacuum Vent	Lock Washer	CS				
Pressure Vacuum Vent	Lock Washer	SS				
Pressure Vacuum Vent	O Ring	VT				
Pressure Vacuum Vent	O Ring Plate	VT				

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Pressure Vacuum Vent	Pallet Pressure	SS				
Pressure Vacuum Vent	Pallet-Vacuum	SS				
Pressure Vacuum Vent	Pantograph assemblies	AL	SS			
Pressure Vacuum Vent	Retainer Plate Pressure	SS				
Pressure Vacuum Vent	Sampling connections	AL	SS			
Pressure Vacuum Vent	Screen	PVC				
Pressure Vacuum Vent	Single point adapter	SS	AL	BN		
Pressure Vacuum Vent	Spacer	CS				
Pressure Vacuum Vent	Spring	CS				
Pressure Vacuum Vent	Spring Button	CS				
Pressure Vacuum Vent	Spring Chamber	AL				
Pressure Vacuum Vent	Stem Guide	CS				
Pressure Vacuum Vent	Stem-Pressure	SS				
Pressure Vacuum Vent	Stud	CS				
Pressure Vacuum Vent	Venturi's	SS				
Pressure Vacuum Vent	Weatherhood	AL				
Small Check Valve, Diaphragm	Body (Screwed)	BZ				
Small Check Valve, Diaphragm	Body Plug (3/8 NPT)	BR				
Small Check Valve, Diaphragm	Cover	SS	BZ			
Small Check Valve, Diaphragm	Diaphragm	BN				
Small Check Valve, Diaphragm	Diaphragm Washer	SS	BR			
Small Check Valve, Diaphragm	Disc Retainer Assembly	SR				
Small Check Valve, Diaphragm	Spring	SS				
Solenoid Control	Body Assy.	BR	SS			
Solenoids	Gasket, Cap	CO				
Solenoids	Gasket, Stuffing Box	Lead				
Solenoids	O-ring Packing	SR				
Solenoids	Port-Piston	BR				
Solenoids	Stuffing box assy.	BR				
Solenoids	Valve Body	BR	SS			
Strainer and Orifice Assy.	Body	BR				
Strainer and Orifice Assy.	Orifice Plug	DE				
Strainer and Orifice Assy.	O-rings	SR				
Strainer and Orifice Assy.	Plugs	BR				
Strainer and Orifice Assy.	Screen	MO				
Tanker Truck Off Loading	Pump	BR	CI			
Tanker Truck Off Loading	Seals	Ni-R	BN	SS		
Valve Position Indicator	Adapter	SS	BR			
Valve Position Indicator	Bushing	SS	BR			
Valve Position Indicator	Gaskets	NBR				
Valve Position Indicator	Housing	SS	BR			
Valve Position Indicator	Housing Assembly	SS	AL			

Table 1 (Fuel Wetted Components)

Component	Item	Material Identifiers (see Table 2)				
Valve Position Indicator	Sight Tube	Glass				
Valve Position Indicator	Sight Tube	Pyrex				
Valve Position Indicator	Stem	SS	BR			
Valve Position Indicator	Stem Adapter	SS	BR			
Valve Position Indicator	Vent valve or plug	SS	BR			
Vertical Turbine Pumps	API 682 Mechanical Seal	BN	SS	CA		
Vertical Turbine Pumps	Bottom Plug	DI				
Vertical Turbine Pumps	Bowl Bearings	CA				
Vertical Turbine Pumps	Bowl Bearings	GR				
Vertical Turbine Pumps	Bowl Bolting	SS				
Vertical Turbine Pumps	Bowls Mil-P-4556E, enamel-Lined	CI				
Vertical Turbine Pumps	Disc	SS				
Vertical Turbine Pumps	Double keyed Impeller	SS				
Vertical Turbine Pumps	Drive Collar	SS				
Vertical Turbine Pumps	Flanged Column Assembly	CS	SS			
Vertical Turbine Pumps	Hex Head Cap Screws	SS				
Vertical Turbine Pumps	Impeller Key	SS				
Vertical Turbine Pumps	Impeller Retaining Ring	SS				
Vertical Turbine Pumps	Impellers (Electroless Nickel Plating)	DI				
Vertical Turbine Pumps	Line Shaft	SS				
Vertical Turbine Pumps	Lineshaft Bearing	CA				
Vertical Turbine Pumps	Mating Ring	Si-C				
Vertical Turbine Pumps	Mechanical Seal Retainer	CI				
Vertical Turbine Pumps	O-Ring	NBR				
Vertical Turbine Pumps	Primary Ring	CA				
Vertical Turbine Pumps	Pump Shaft	SS				
Vertical Turbine Pumps	Retainer	SS				
Vertical Turbine Pumps	Rigid Couplings	SS				
Vertical Turbine Pumps	Sand Collar Set Screw	SS				
Vertical Turbine Pumps	Seal Retainer Bearing	DI				
Vertical Turbine Pumps	Snap Ring	SS				
Vertical Turbine Pumps	Spring	SS				
Vertical Turbine Pumps	Suction Bearing	CA				
Vertical Turbine Pumps	Suction Bell	CS	SS			
Vertical Turbine Pumps	Suction Case	DI				
Vertical Turbine Pumps	Suction Case Bearing	CA				
Vertical Turbine Pumps	Top Bowl Bearing	CA				
Vertical Turbine Pumps	Tubing	SS				
Vertical Turbine Pumps	Wear Rings	SS				

Table 2 (Table 1 Identifier Composition)

Table 1 Identifier	Common Name	Composition	Proportions	Polymer	Elemental Composition
Ac	Teflon and NBR	PTFE + NBR		x	NBR > C, H, N; PTFE > F, C
DE	Delrin			x	C,H,O
EP	Epoxy			x	C,H,O, possible hetero atoms.
FIB	Fiber			x	Si, C,
FL	Fluorosilicone	F+ Si+		x	F, Si,
FML	Flexible Membrane Liner			x	
FPM	Fluorocarbon	(PTFE)		x	F,C,H
FRP	Fiber Reinforced Plastic			x	
Hy	Hycar	Nitrile Carboxyl-functional butadiene copolymer + with acrylonitrile		x	HNBR
NBC	Neoprene & cork			x	
NBR	Butadiene Acrylonitrile Copolymer	NBR		x	C,H,N
NE	Neoprene			x	C,Cl,H
NR	Nitrile rubber	Buna-N or NBR		x	C,H,N
PC	Polyurethane Coated			x	N,C,H,O
PF	Paper Fiber			x	
PV	PVC			x	Cl,C,H
SR	Syn Rubber			x	
TF	Teflon	PTFE		x	F,C
UR	Urethane			x	C,N,H,O
VI	Viton	F+co-polymers	66-70%, C-H balance	x	F,C,
Al	Aluminum	Al			
BN	Buna-N	NBR		x	C,H,N
BR	Brass	Cu + Zn	50-65%, 35-50%		
BZ	Bronze	Cu + Zn + SN [or Al, Ar, Pb, Ni, Mn]	60-90%, 5-40%, 1-5%,		
CA	Carbon	C			
CP	Cadmium over CS	Cd+ Fe+			
CI	Cast Iron	Fe			
CO	Copper	Cu			

Table 2 (Table 1 Identifier Composition)					
Table 1 Identifier	**Common Name**	**Composition**	**Proportions**	**Polymer**	**Elemental Composition**
CS	Carbon Steel	Fe+ C+			
CT	Steel tank coating	Fe+			
DI	Iron	Fe			
GR	Graphite	C			
IN	austenitic nickel-chromium-alloys	Ni+ Cr+ Fe+ Mo+ Nb+ Co+++	44-72%, 14-30%, 3-9%, 2-8%, 1-5%, 1-10%		
MO	Monel	Ni + Cu	near 50/50		
NBS	Naval Brass	Copper + Zinc + Tin	59%, 40%, 1%		
Ni-R	Ni-Resist	Fe+ Ni+ Cu+ C+ Cr++	~70%, 13-18%, 5-8%, 0.1-3%, 1-		
NP	Nickel Plated	Ni+ Fe++			
Oi	Oillite bronze	Cu + Fe + Sn	87-91%, 1%, 9-11%; porous structure		
Si-C	Silicon Carbide	C+ Si	+/- 50-50%		
SS	Stainless Steel	Fe+ C+ Va	90%, .2-2%		

Attachment 3

Metal or Mineral Content in Approved Fuel Tank Epoxy Coatings

Mfg.	Commercial Name / DOD Identifier	Description	Component	CAS #	Min %	Max %
UFGS-09 97 13.17	Navy Formula 152, type IV, Primer	Epoxy Polyamide, B	Aluminum Silicate	0012141-46-7		13
PPG	Amercoat 133 primer		barium sulfate	0007727-43-7	30	60
International Paint, LLC	Interline 604 part A,	THA660 Grade C	Barium sulfate	0007727-43-7	10	25
International Paint, LLC	Intergard 264, part A,	FPD052 Grade B,C	Barium sulfate	0007727-43-7	10	25
PPG	Amercoat 333 topcoat		barium sulfate	0007727-43-7	30	60
International Paint, LLC	Interbond 998 A	KRA 922 grey,	Barium sulfate $BaSO_4$	0007727-43-7	25	50
International Paint, LLC	Interbond 998 A	KRA 922 grey,	Bisphenol A − Epichlorohydrin C_3H_5ClO	0025068−38−6	25	50
PPG	Amercoat 333 topcoat		crystalline silica respirable (<10 microns)	0014808-60-7	0	1
PPG	Amercoat 134	WO10441 Gray ral 7032 Resin	crystalline silica respirable (<10 microns)	0014808-60-7	0	1
Sherwin Williams	Nova-Plate UHS Epoxy A	B62W220 topcoat	crystalline silica respirable (<10 microns)	0014808-60-7	0	0.1
Sherwin Williams	Fast-Clad ER epoxy B,	B62V230 Hardener	crystalline silica respirable (<10 microns)	0014808-60-7	1	0.8
PPG	AMERCOAT 236, Grade C	WO4050110 / 236B1642 Resin	crystalline silica respirable (<10 microns)	0014808-60-7	10	30
Sherwin Williams	Tankguard, part A	N11L100	crystalline silica respirable (<10 microns)	0014808-60-7	13	13
PPG	Sigma Edgeguard Base	5428A, primer yellow base	Magnesium Silicate (Talc)	0014807-96-6	1	10
PPG	Sigma Edgeguard	Base White 7000	Magnesium Silicate (Talc)	0014807-96-6	3	7
Sherwin Williams	Dura-Plate UHS epoxy, A	B62H210 primer	Magnesium Silicate (Talc)	0014807-96-6	4	4

Mfg.	Commercial Name / DOD Identifier	Description	Component	CAS #	Min %	Max %
Sherwin Williams	Dura-Plate UHS epoxy A	B62W210	Magnesium Silicate (Talc)	0014807-96-6	4	4
PPG	Sigma Edgeguard	Primer Base 3035	Magnesium Silicate (Talc)	0014807-96-6	5	10
International Paint, LLC	Interline 783 Part A	topcoat	Magnesium Silicate (Talc)	0014807-96-6	10	25
Sherwin Williams	Nova-Plate UHS epoxy A	B62H220 primer	Magnesium Silicate (Talc)	0014807-96-6	12	12
Sherwin Williams	Nova-Plate UHS Epoxy A	B62W220 topcoat	Magnesium Silicate (Talc)	0014807-96-6	13	13
Sherwin Williams	Tankguard, part B	N11L101	Magnesium Silicate (Talc)	0014807-96-6	25	25
Sherwin Williams	Seaguard 5000 part A,	N11A350, Grade C	Magnesium Silicate (Talc)	0014807-96-6	31	31
Sherwin Williams	Seaguard 5000 part B,	N11V350, Grade C	Magnesium Silicate (Talc)	0014807-96-6	35	35
International Paint, LLC	Interbond 998 A	KRA 922 grey,	Magnesium Silicate (Talc)	0014807-96-6	1	10
PPG	AMERCOAT 236, Grade C	WO4050110 / 236B1642 Resin	Magnesium Silicate (Talc)	0014807-96-6	10	30
International Paint, LLC	Interline 624 epoxy A	THA 626 primer	Magnesium Silicate (Talc)	0014807-96-6	10	25
International Paint, LLC	Interline 624 epoxy A	THA 623 topcoat	Magnesium Silicate (Talc)	0014807-96-6	10	25
International Paint, LLC	Interline 783 Buff A	THA 782 topcoat	Magnesium Silicate (Talc)	0014807-96-6	10	25
International Paint, LLC	Interline 604 part A,	THA660 Grade C	Magnesium Silicate (Talc)	0014807-96-6	25	50
International Paint, LLC	Intergard 264, part A,	FPD052 Grade B,C	Magnesium Silicate (Talc)	0014807-96-6	25	50
UFGS-09 97 13.17	Navy Formula 152, type IV	Epoxy Polyamide, B	Magnesium Silicate (Talc)	0014807-96-6		35

Mfg.	Commercial Name / DOD Identifier	Description	Component	CAS #	Min %	Max %
UFGS-09 97 13.17	Navy Formula 152, type IV, Primer	Epoxy Polyamide A	Magnesium Silicate (Talc)	0014807-96-6		37
UFGS-09 97 13.17	Navy Formula 152, type IV, Primer	Epoxy Polyamide, B	Magnesium Silicate (Talc)	0014807-96-6		25
PPG	Amercoat 333 topcoat		Mica (note 1)	0012001-26-2	1	5
International Paint, LLC	Interline 624 epoxy A	THA 626 primer	Mica (note 1)	0012001-26-2	1	10
International Paint, LLC	Interline 624 epoxy A	THA 623 topcoat	Mica (note 1)	0012001-26-2	1	10
PPG	AMERCOAT 236, Grade C	WO4050110 / 236B1642 Resin	Mica-group minerals (note 1)	0012001-26-2	1	5
PPG	Sigma Edgeguard Base	5428A, primer yellow base	Nepheline Syenite (note 2)	0037244-96-5	10	25
International Paint, LLC	Interline 624 epoxy A	THA 626 primer	Nepheline syenite (note 2)	0037244-96-5	1	10
International Paint, LLC	Interline 624 epoxy A	THA 623 topcoat	Nepheline syenite (note 2)	0037244-96-5	1	10
PPG	Sigma Edgeguard	Base White 7000	Nepheline syenite (note 2)	0037244-96-5	10	30
PPG	Sigma Edgeguard	Primer Base 3035	Nepheline syenite (note 2)	0037244-96-5	10	30
International Paint, LLC	Interline 604 part A,	THA660 Grade C	p−Chloro−a,a,a−trifluorotolue n e	0000098−56−6	1	10
International Paint, LLC	Intergard 264, part A,	FPD052 Grade B,C	p−Chloro−a,a,a−trifluorotolue n e	0000098−56−6	1	10
PPG	Sigma Edgeguard	Primer Hardner	Proprietary silane	Proprietary	1	5
PPG	Sigma Edgeguard Base	5428A, primer yellow base	Titanium Dioxide	0013463-67-7	1	10
International Paint, LLC	Interline 783 Part A	topcoat	Titanium dioxide	0013463-67-7	1	10
PPG	Sigma Edgeguard	Base White 7000	Titanium Dioxide	0013463-67-7	1	5
PPG	Sigma Edgeguard	Primer Base 3035	Titanium Dioxide	0013463-67-7	1	5
PPG	AMERCOAT 236, Grade C	WO4050110 / 236B1642 Resin	Titanium Dioxide	0013463-67-7	1	5
PPG	Amercoat 333 topcoat		Titanium Dioxide	0013463-67-7	3	7

Mfg.	Commercial Name / DOD Identifier	Description	Component	CAS #	Min %	Max %
Sherwin Williams	Dura-Plate UHS epoxy A	B62W210	Titanium Dioxide	0013463-67-7	4	4
PPG	Amercoat 133	WO10441 Gray ral 7032 Resin	Titanium Dioxide	0013463-67-7	5	10
Sherwin Williams	Nova-Plate UHS Epoxy A	B62W220 topcoat	Titanium Dioxide	0013463-67-7	6	6
Sherwin Williams	Nova-Plate UHS epoxy A	B62H220 primer	Titanium Dioxide	0013463-67-7	7	7
Sherwin Williams	Fast-Clad ER epoxy A	B62S230	Titanium Dioxide	0013463-67-7	8	8
Sherwin Williams	Dura-Plate UHS epoxy, A	B62H210 primer	Titanium Dioxide	0013463-67-7	14	14
Sherwin Williams	Seaguard 5000 part A,	N11A350, Grade C	Titanium Dioxide	0013463-67-7	17	17
Sherwin Williams	Fast-Clad ER epoxy, A		Titanium Dioxide	0013463-67-7	21	21
Sherwin Williams	Tankguard, part A	N11L100	Titanium Dioxide	0013463-67-7	40	40
UFGS-09 97 13.17	Navy Formula 152, type IV	Epoxy Polyamide A	Titanium dioxide	0013463-67-7		47
UFGS-09 97 13.17	Navy Formula 152, type IV, Primer	Epoxy Polyamide A	Titanium dioxide	0013463-67-7		9
UFGS-09 97 13.19	AF Topcoat over formula 152	Polyurethane A	Titanium dioxide	0013463-67-7		5
International Paint, LLC	Interline 604 part A,	THA660 Grade C	Titanium dioxide	0013463-67-7	1	10
International Paint, LLC	Interline 624 epoxy A	THA 626 primer	Titanium dioxide	0013463-67-7	1	10
International Paint, LLC	Interline 624 epoxy A	THA 623 topcoat	Titanium dioxide	0013463-67-7	1	10

Mfg.	Commercial Name / DOD Identifier	Description	Component	CAS #	Min %	Max %
International Paint, LLC	Interline 783 Buff A	THA 782 topcoat	Titanium dioxide	0013463-67-7	1	10
International Paint, LLC	Interbond 998 A	KRA 922 grey,	Titanium dioxide	0013463-67-7	1	10
International Paint, LLC	Intergard 264, part A,	FPD052 Grade B,C	Titanium dioxide	0013463-67-7	1	10
UFGS-09 97 13.17	Navy Formula 152, type IV, Primer	Epoxy Polyamide A	Yellow Iron Oxide	0051274-00-1		2
Note 1	**Mica**	$X_2Y_{4-6}Z_8O_{20}(OH,F)_4$	X is K, Na, or Ca or less commonly Ba, Rb, or Cs			
			Y is Al, Mg, or Fe or less commonly Mn, Cr, Ti, Li, etc.;			
			Z is chiefly Si or Al, but also may include Fe^{3+} or Ti.			
		Elemental Comp.	%			
Note 2	**Nepheline syenite**	SiO_2	0.5499			
		Al_2O_3	0.2096			
		Na_2O	0.0823			
		K_2O	0.0558			
		CaO	0.0231			
		Fe_2O_3	0.0225			
		FeO	0.0205			
		H_2O	0.0147			
		MgO	0.0077			
		TiO2	0.006			
		MnO	0.0015			
		P_2O_5	0.0013			

Attachment 4

Location A Lab Filtration filter analysis.

A set of thirteen filters used in jet fuel delivery systems were examined for possible contaminants. The 47mm filters are used to capture particles from 1 gallon of fuel and to determine the time necessary for filtration. These samples, identified as DLA 1 to DLA 13 were taken from systems with relatively clean fuels showing minimal contamination.

Macro images were taken to document the conditions of the as received filters. The filters mostly show minimal if any particle contamination. Of the filters showing particles, Sample DLA-5 showed the heaviest loading while still well below the 1 mg/ℓ limit. Particulate mass, when available, has been included with filter identifier.

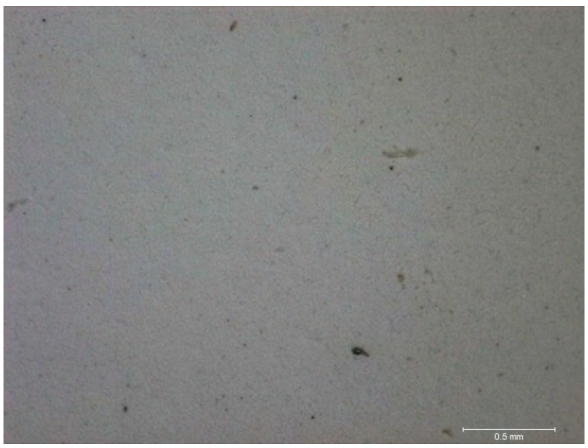


Image of Filter DLA-1

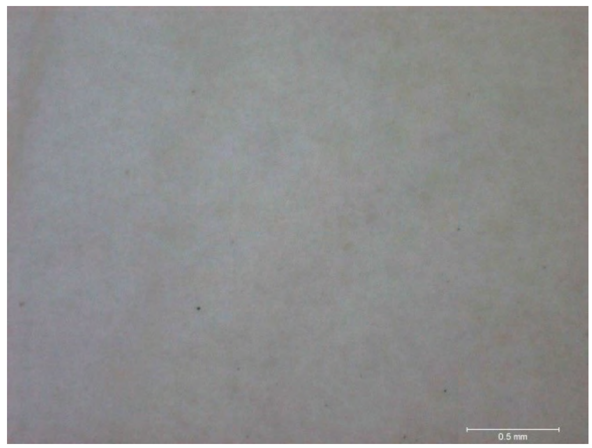


Image of Filter DLA-3

Image of Filter DLA-2

Image of Filter DLA-4

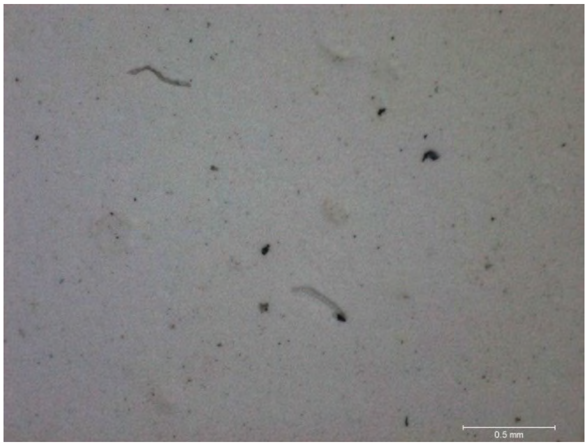


Image of Filter DLA-5

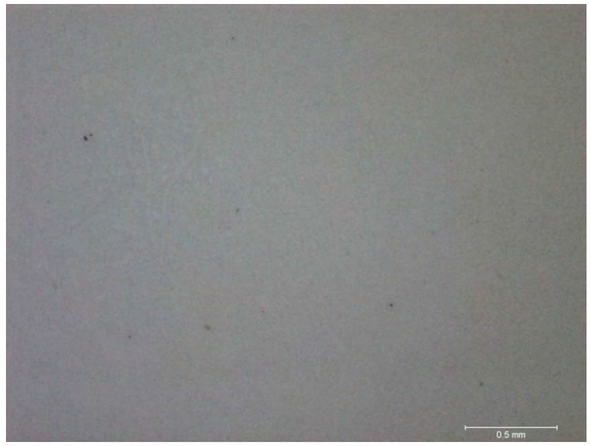


Image of Filter DLA-8

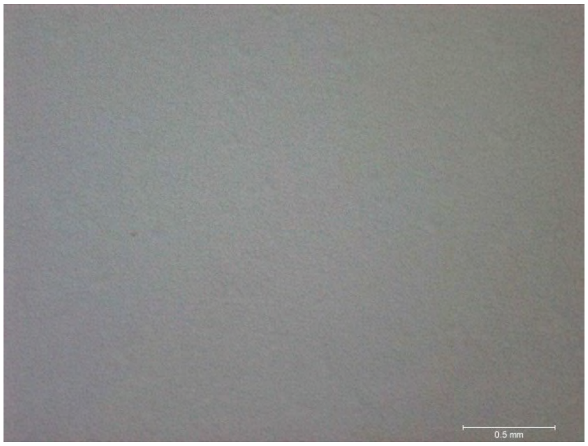


Image of Filter DLA-6 (0.5 mg/ ℓ)

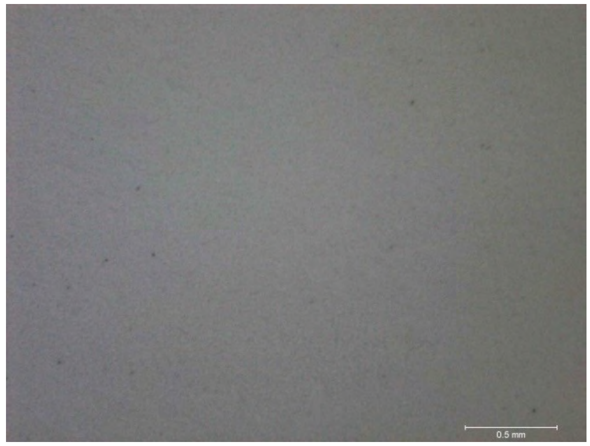


Image of Filter DLA-9

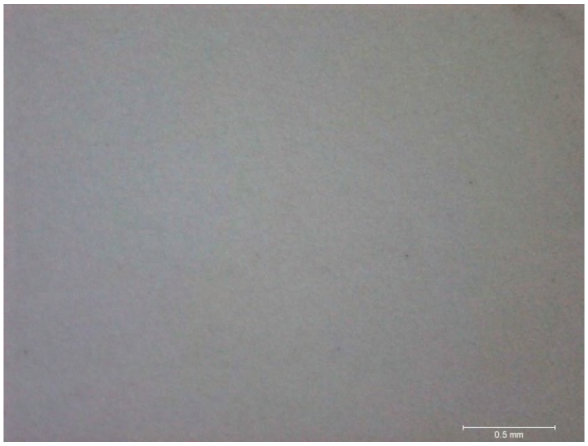


Image of Filter DLA-7

Image of Filter DLA-10

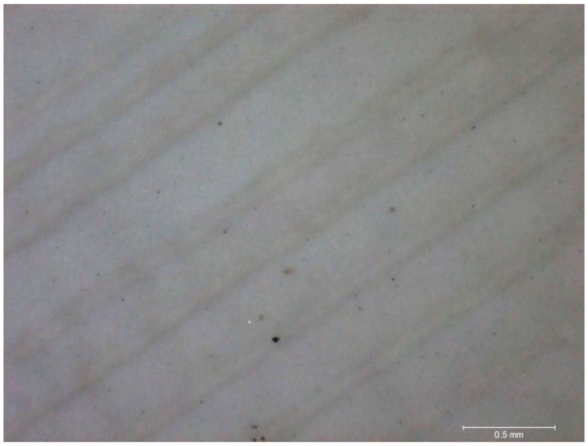


Image of Filter DLA-11

Image of Filter DLA-13

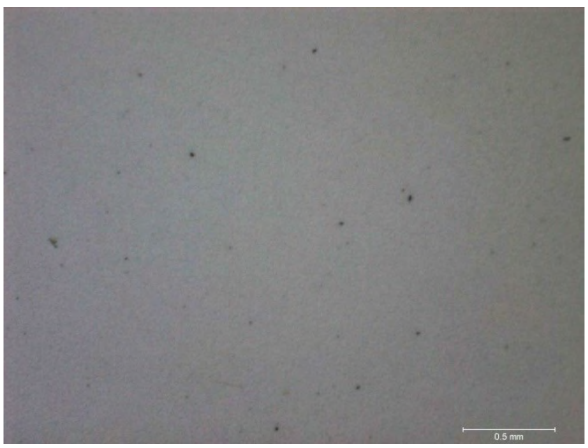


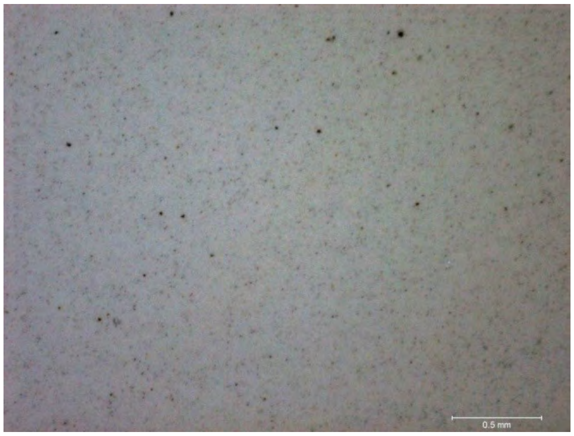
Image of Filter DLA-12

Some very minor discoloration was observed on a few filters, specifically DLA-2, DLA-3, and DLA-11. Below is shown an unmagnified image of these filters next to the blank filter (DLA-13). The filter numbers in the image ascend from left to right. The blank filter (DLA-13) is on the far right. As seen in the image, the level of discoloration is also very minimal.

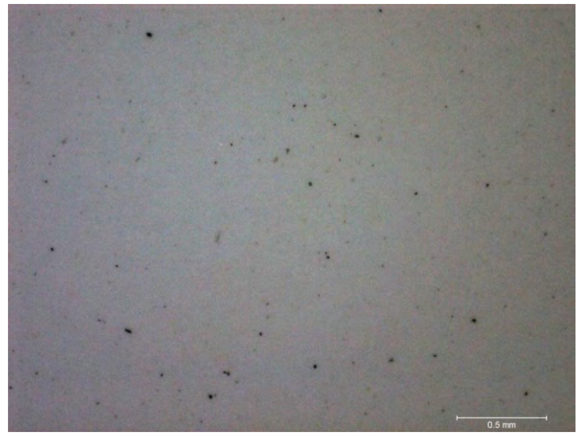

Image of Filters DLA-2, DLA-3, DLA-11, and DLA-13 (l-r)

Location B Filtration Filter Analysis

Light Microscopy Images, (LMI) of the filters are shown below. Sample locations are listed with each photomicrograph. The filters in this set showed varying degrees of a pink tint in the center of the filters however all QC tests were well within limits. The pink color does not show well in these images.



DLA 14, (Tank #6 Location B-1,) 0.4mg/ℓ Particulates



DLA 15, (Issue rack 53, Location B-1) 0.1mg/ℓ Particulate

The filter referenced as DLA22 was examined for elemental composition. Sections in the middle of the filter and on a clean white edge were analyzed by X-ray Fluorescence (XRF). An overlay of the XRF spectra of the two examined positions is shown below. The XRF spectra are very similar to each other and show no iron or other inorganic components.

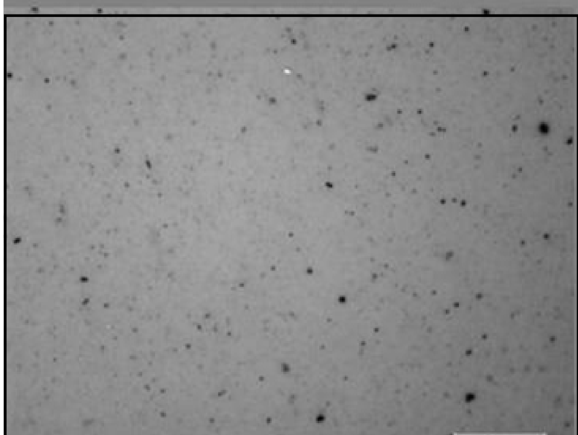
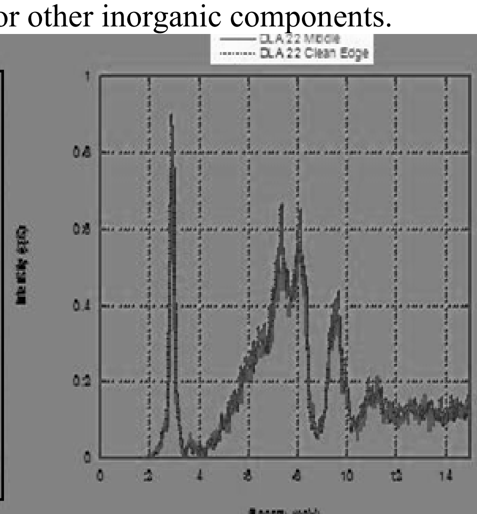


Image of Filter DLA22,
(Receipt sample – filter #2, [redacted]

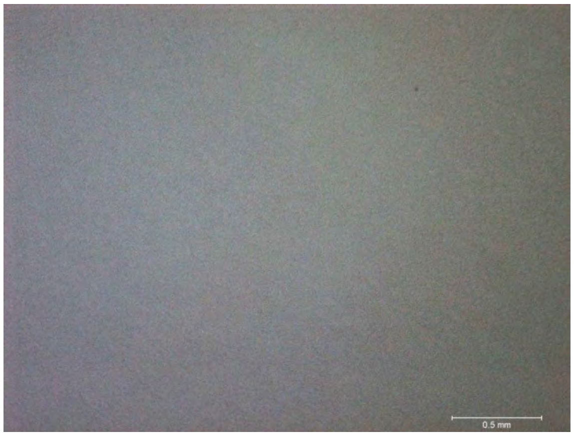


Overlay of XRF Spectra of Middle and Clean Edge Area of Filter DLA22

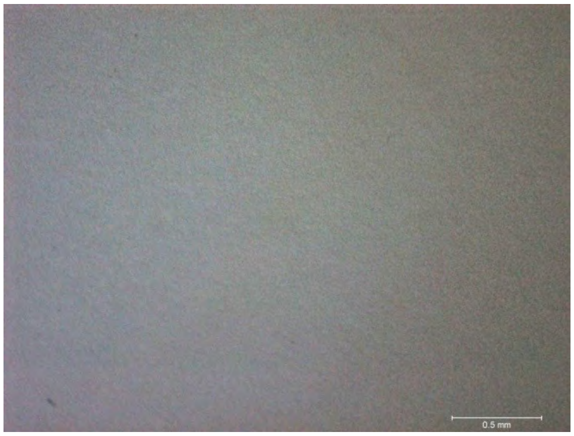
Location C Filtration Filter Analysis

Very Low Contaminant Level

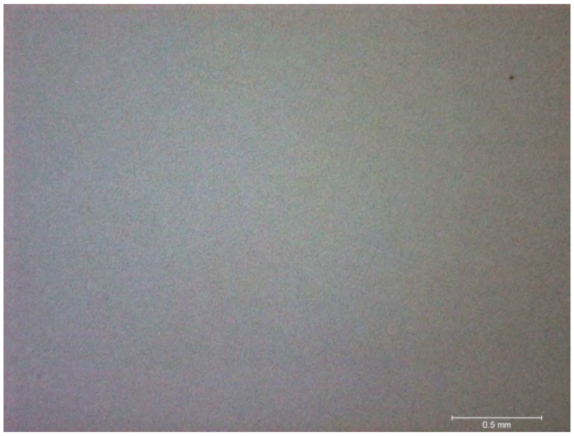
Light Microscopy images are shown below. Filtration samples were consistently well below limits. Sample locations are listed with each photomicrograph.



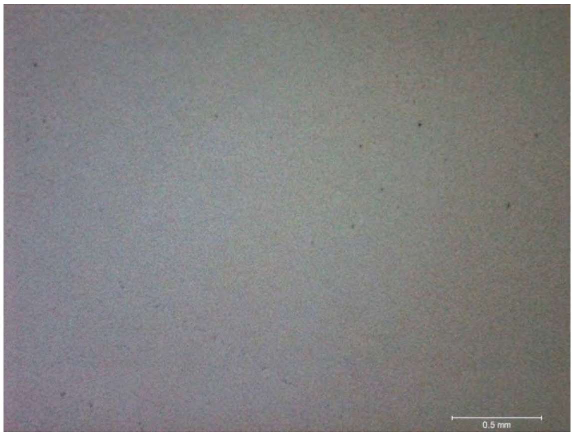
DLA16, (14-1293), (Location C-1 #2)



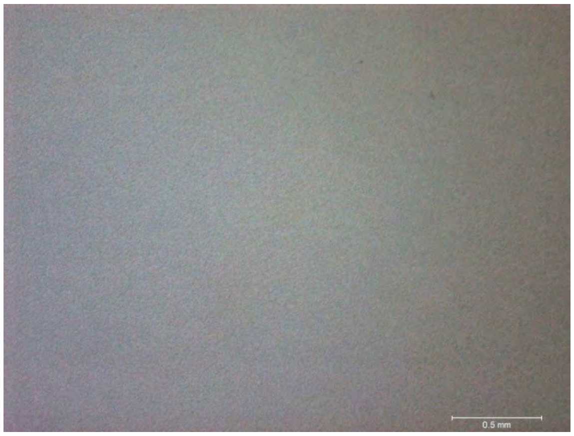
DLA 19, (Low refueling truck #2)



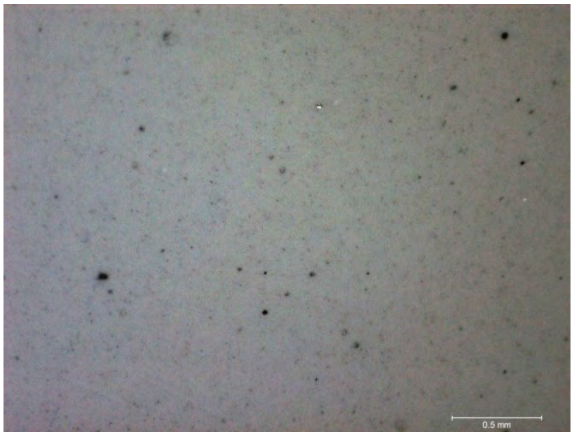
DLA17, (14-1284), (Location C-2 refueling truck #9)



DLA20, (Location C-3 fillstand #2)



DLA18, (Location C-4 fillstand #2)



DLA21, (Location C-3 refueling truck #49)

Location D pipeline receipt lab filtration sample filters.

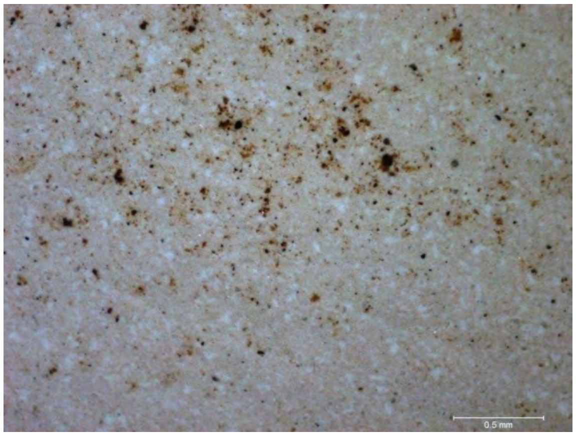
Testing is run with two filters in tandem, the darkest filter below is the top filter. In each set, the top filter showed some discoloration and/or debris. Below are images of the top and bottom filters from each set.

Sample DLA 25. Lab filtration test on second pipeline sample, 30 minutes after start of flow. (0.3 mg/ℓ, max 1.5 mg/ℓ)

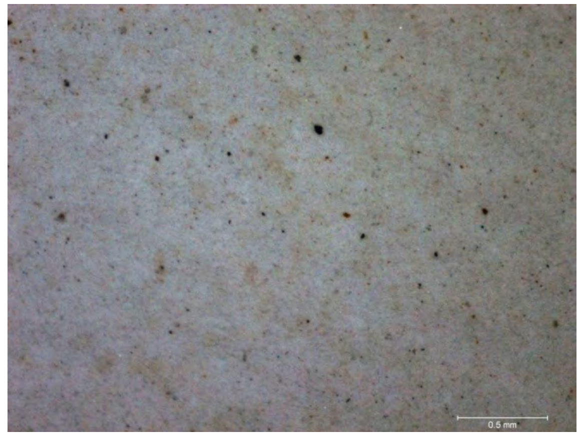
Sample DLA 26. Lab filtration test on initial pipeline receipt sample, 5 minutes after start of flow. (10.2 mg/ℓ, max 1.5 mg/ℓ)

Sample DLA 27. Lab filtration sample of pipeline receipt, prior to delivery completion (0.1 mg/ℓ, max 1.5 mg/ℓ)

Light Microscope Image of Lab Filtration filters.



DLA 25 Top Filter



DLA 27 Top Filter

DLA 26 Top Filter

Additional examination was performed using XRF on the filter samples referenced as DLA 25 - DLA 27 for elemental analysis.

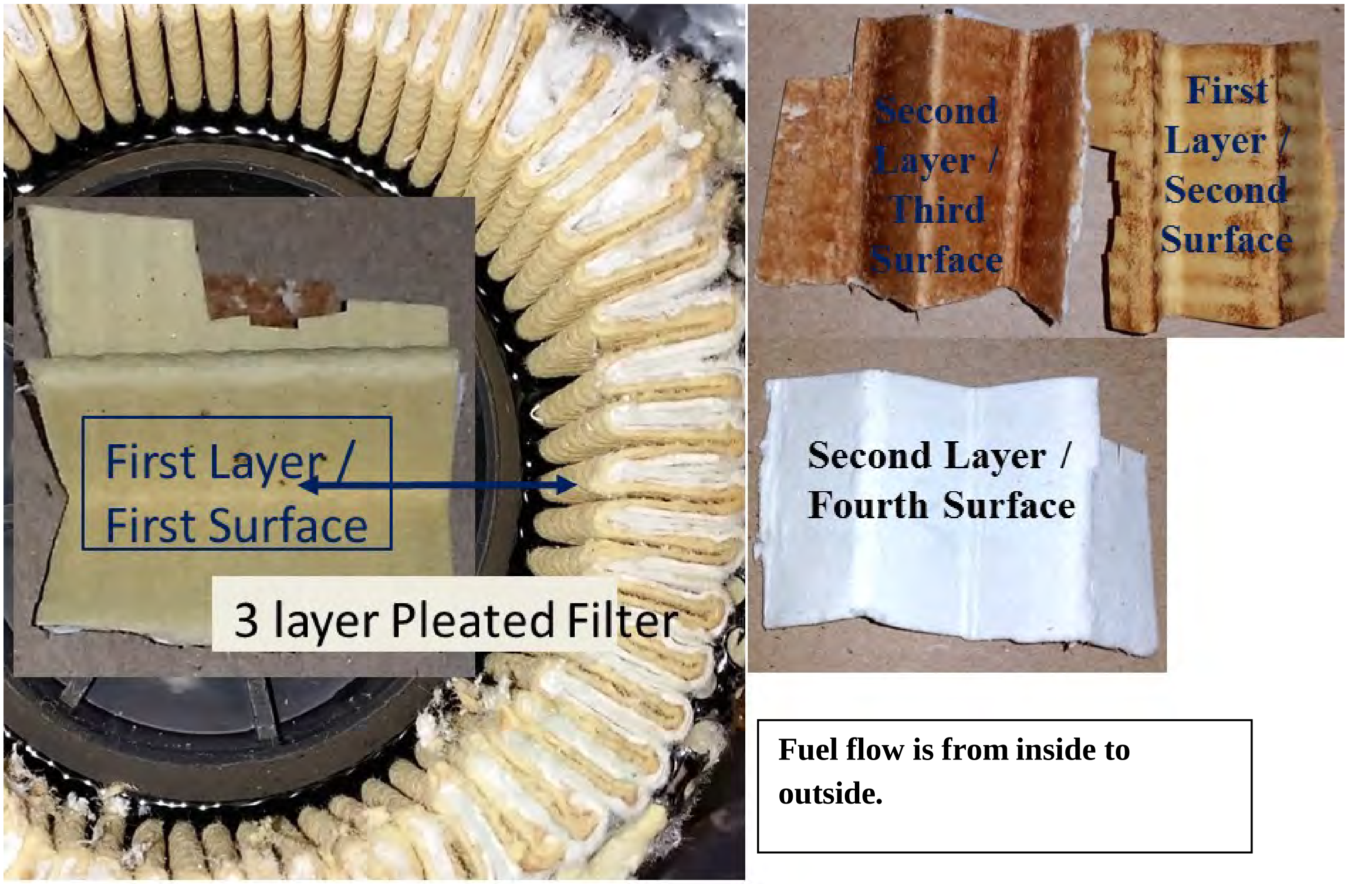
DLA 25. Semi-quantitative analysis shows several spots rich in iron and oxygen. The elemental analysis shows carbon and oxygen from the filter material along with iron and trace amounts of sodium, sulfur, chlorine, and potassium.

DLA 26: Heavy loading of iron throughout the examination area.

DLA 27: Areas of lower iron concentration, which is consistent with the other analyses that indicated this sample to have the lowest iron concentration of the three.

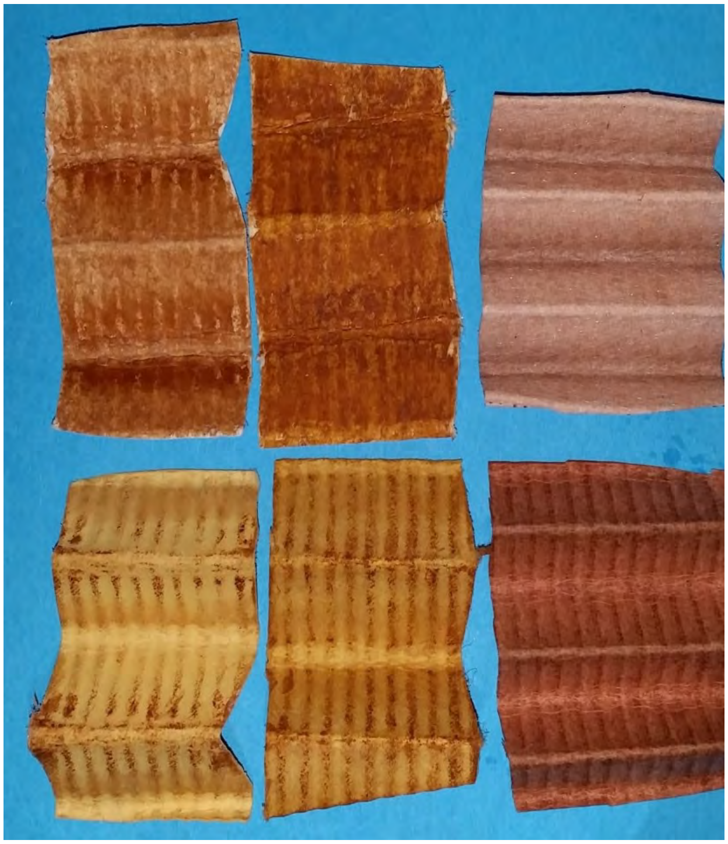
The analyses performed on the pieces of the three filters confirm the residues to be general “rust” (iron oxide hydroxide hydrate). The presence of chlorine, sodium, and potassium indicates that chlorides of sodium and/or potassium might be present. These could have acted as a potential accelerant in a corrosion process producing the rust residue. Some sulfur was also detected in some of the examined areas and could also have played some role in the corrosion process.

Filter Separator Dissection for Examination



Fuel flow is from inside to outside.

Sample DLA 23 is a filter / separator element from the Location D receipt pipeline filter / separator unit. This element was removed from service with less than 1 week of service due to high delta pressure across the filtration unit. It became evident on inspection that the red layer deposited between the second layer and first layer was the cause of high delta pressure. None of the other layers of filtration showed any significant particle load. Elemental analysis agreed with the analysis of samples DLA 25-27.

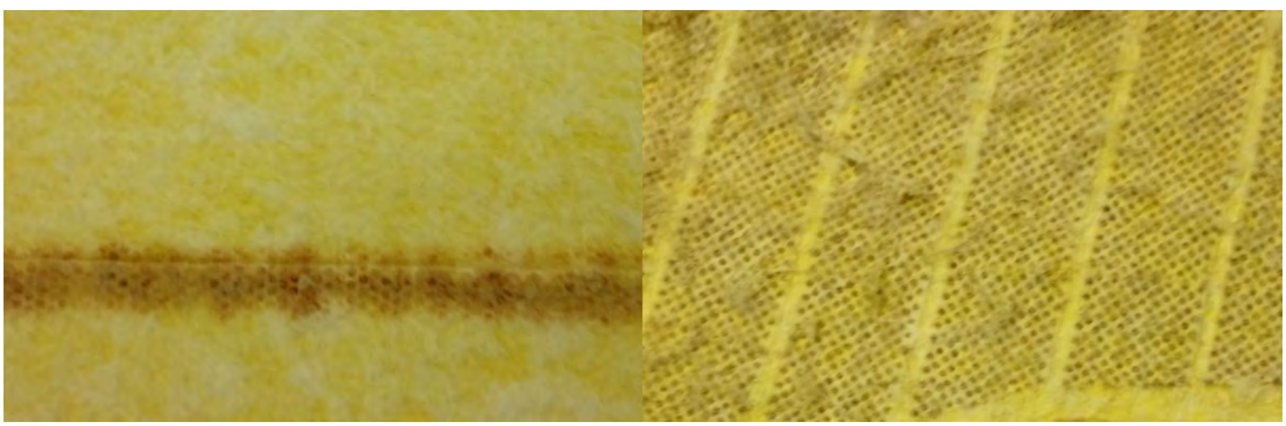


Layers and Surfaces are numbered radially inside to outside.

Layer 2 – Surface 3 DLA 23 (Left, Middle) heavy surface loading. DLA 24 (Right) light surface loading.

Layer 1- Surface 2: DLA 23 (Left, Middle) moderate to light surface loading. DLA 24 (Right) moderate loading.

DLA Sample 23 & 24 Comparison.
DLA Sample 23, (Left, Middle), was removed with less than one week in service, while, DLA Sample 24 was in service for 3 years at Location B-2.



DLA sample 23 & 24 Comparison.
DLA Sample 23 (Left) Layer 3 – Surface 5, immediately outboard of perforated steel tube. Particle loading is visible only visible in small stripe running the length of the element.
DLA Sample 24, Layer 3 – Surface 7 also immediately outboard of the axial steel perforated tube. Particle loading was seen to be uniformly distributed around the complete circumference.

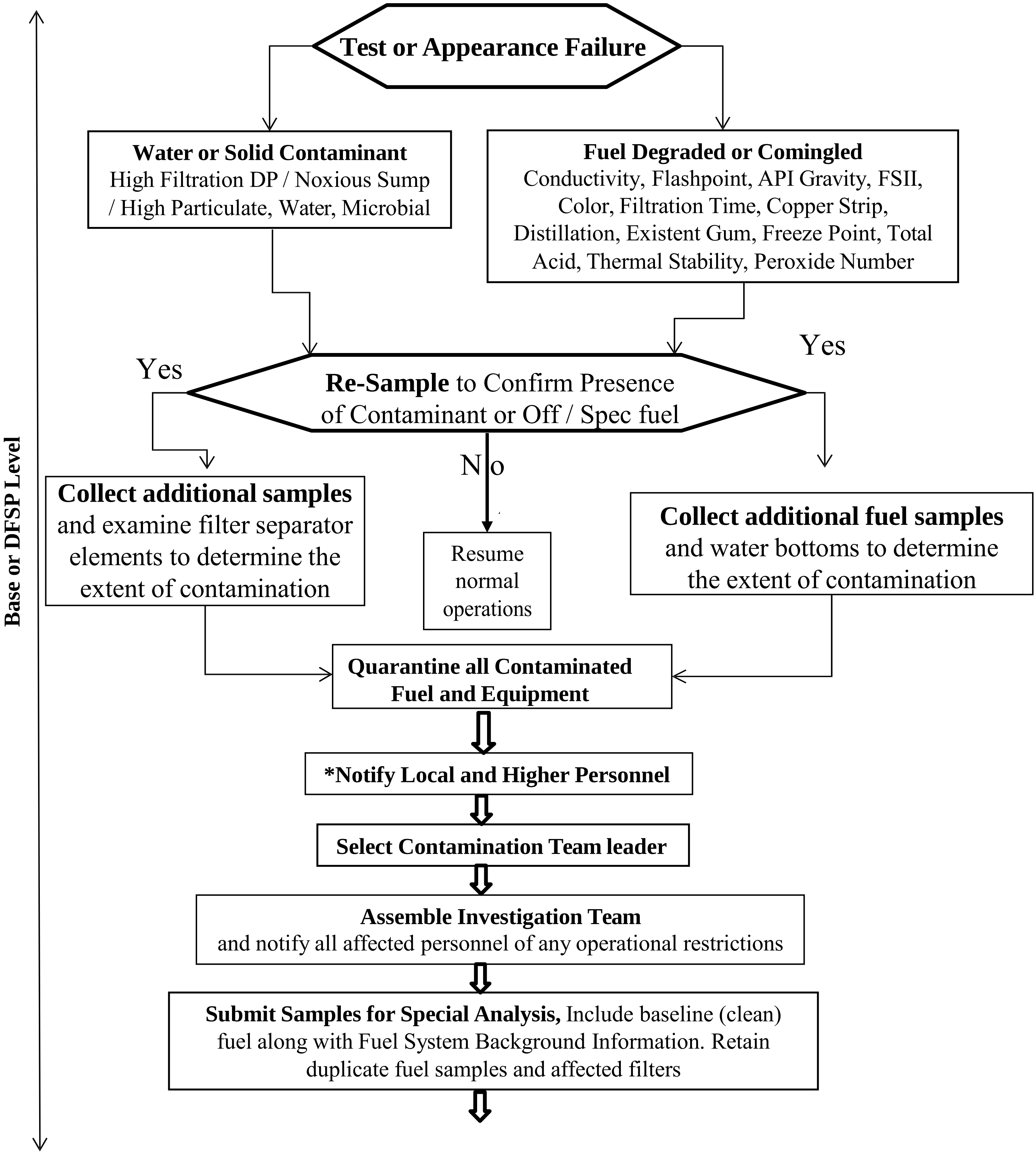
Attachment 5

Crisis Management Approach to Contamination Identification and Mitigation

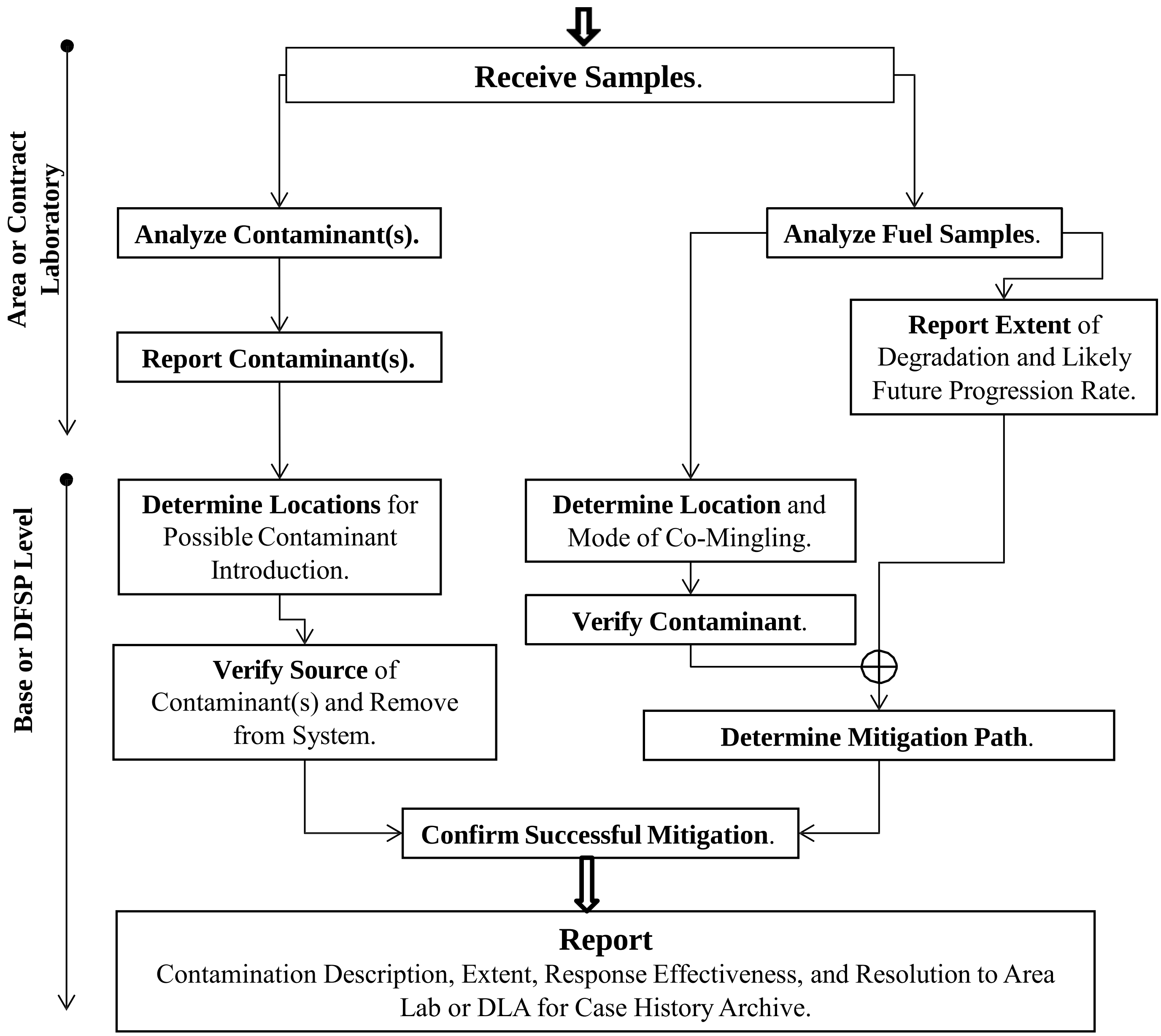
<table>
<tr><th colspan="3">Contamination</th><th colspan="2">Off Spec</th></tr>
<tr><td colspan="3">Confirm and Define Contaminant</td><td colspan="2">Confirm Spec test failure</td></tr>
<tr><td>Water</td><td>Particulate</td><td>Microbial Growth</td><td>Commingling</td><td>Deterioration</td></tr>
<tr><td colspan="5">Determine Extent of Contamination</td></tr>
<tr><td colspan="5">Quarantine Affected System(s) & Equipment</td></tr>
<tr><td colspan="5">Collect Samples for Special Analysis to Include Baseline Contaminated Fuel, Retain Filters & Duplicate Samples for Further Evaluation</td></tr>
<tr><td colspan="5">Submit Samples for Special Analysis</td></tr>
<tr><td colspan="5">** Make Appropriate Local & Higher HQ Notifications
Is it Necessary to Reduce Operational Capability?
Do we understand the problem well enough to solve locally with increased filtration, water removal, or other enhanced housekeeping effort?</td></tr>
<tr><td colspan="5">If too many unknowns for simple solutions then:
Select Mitigation Manager (Local or Area</td></tr>
<tr><td colspan="5">Assemble Investigation Team, Disseminate All Available Information, (Include supporting documentation: Equipment records, Analysis History)</td></tr>
<tr><td colspan="3">Analyze Contaminants</td><td colspan="2">Analyze Fuel Samples</td></tr>
<tr><td colspan="5">Report Results
Result details should be detailed enough to support likely sources based on field conditions.</td></tr>
<tr><td colspan="5">Refined Contaminate Identification / Typical Cause / Probable Source</td></tr>
<tr><td colspan="5">Choose Mitigation Process</td></tr>
<tr><td colspan="5">Confirm Successful Mitigation, (re-sample)</td></tr>
<tr><td colspan="5">All team members: Report contamination extent, description, response, and resolution to Area Labor DLA for inclusion in Case History Archive</td></tr>
</table>

**If product is capitalized, notification should be IAW procedures outlined in MIL-STD 3004. If product is non-capitalized, notification should be IAW service-directed requirements (preferably via a Product Quality Deficiency Report (PQD)).

Contamination Investigation Work Flow



Work Flow (cont.)



* If product is capitalized, notification should be IAW procedures outlined in MIL- STD 3004. If product is non-capitalized, notification should be IAW service-directed requirements (preferably via a Product Quality Deficiency Report (PQDR).

Attachment 6

Typical Laboratory Instrumentation for Unknown Contaminant Analysis

Instrument	Sample Composition	Results Expected	Limitations
GC-MS[1]	Fuel	Column dependent "fingerprint", signal evolution, (time), is proportional to mass of sample molecule and it's affinity to column coating. Amplitude of signal is proportional to concentration of ion fragments, (MS), number of carbon atoms, (FID, organics only)	Components are identified by searching libraries of pure component spectra stored in the instrument's computer memory. Comparative analysis; should properly have baseline samples. Considerable operator skill may be necessary in order to properly choose between several "matches" in spectral library. Prior experience in evaluating hydrocarbon liquids is absolutely necessary to avoid errors in interpretation.
GC-FID[1]	Fuel		
GC-FTIR[1]	fuel	FTIR Fingerprint (atomic bond information) of sample molecule	
LC-MS[1]	fuel	Molecular mass and polarity "fingerprint"	
Electrode (pH, ISE, etc.)	Water or fuel / oil	Determines how acidic or basic a solution is.	
FTIR	liquid or solid	Bulk analysis of sample for type of atomic bonds present	Works best on pure sample or single contaminant. Signals from all components are superimposed.
Raman	Fuel or Water Bottom	Produces a molecular "fingerprint"	
ICP-AES	Fuel	Elemental analysis, usually looking for metal content in high ppm to mid ppb concentration.	Very low concentrations may leave test solution before analysis is complete
Microscopy, Light / SEM	Solids /Particles or Filter Residue	Particle size and shape, some id's are obvious by shape or color, others are not obvious without extensive experience in particle identification.	Identification tends to be either obvious, (as metal shavings or fibers), or ambiguous.
UV-VIS	Fuel or Water Bottom	May be useful to quantify dye or comingled liquid content.	No comprehensive spectral libraries are available to compare against actual fuel contaminants.
XRF	Solids /Particles or Filter Residue	Elemental analysis	Elemental percentage in single particles or across field of view. Most accurate when standards with same composition are available for comparison.
SEM/EDS	Solids /Particles or Filter Residue	Elemental analysis at high magnification for particles less the 10um	
ATP	Water or Fuel	Microbial activity evaluation: minimal, active, very active. Re-sample and re-test to verify active and very active readings.	Time sensitive, should be run no later 2 to 4 hours after sampling or 24 hours after acquisition if stored on ice.

[1]GC- instruments, (Gas Chromatography), utilize a long packed tube to separate sample components, propelled by a carrier gas. LC-instruments, (Liquid Chromatography), utilize a liquid carrier instead of a gas carrier. Columns are chosen to separate suspected components and in general a column suitable for fuel analysis is not suitable for water analysis. Various detectors, sensitive to different changes in physical properties, are arranged at the column exit to produce a signal that is recorded as a "chromatograph". Results are reported in order of "goodness of fit". If there are multiple 'hits' with a high percentage of agreement the chemist must either use a more sensitive test or rate the results base on his knowledge the sample history.

Attachment 7

Special Sample Acquisition

Special sampling procedures are used whenever it is necessary to determine a source for fuel phase contamination or when the water phase in a fuel sample or sump drain is abnormally colored, contains a high load of particulates, appears to be corrosive or forms a stable emulsion with the fuel phase when shaken.

Note: Normal Sampling Scheduling and Procedures are contained in MIL-STD 3004D and service directives.

Water or Solid Contaminant

High Filtration DP, Noxious Sump, High Particulate, Microbial.

Re-sample from failed sample location, separate water phase if present and re-test.

If failure is repeated evaluate possible extent of contaminant.

Sample upstream and downstream from first location to find extent of suspected contamination.

- Sump and low point samples:
  - Keep water bottom sample, divide into 2 identical samples, prepare 1 sample for area laboratory.
  - Examine water bottoms for evidence of fungal or bacterial growth. Test for PH.
  - Record observations.
- Fuel all level and line samples:
  - Divide Fuel sample into two identical samples.
  - Test one bottle for failure condition.
  - Save second bottle for area lab or Tech team.
  - Save and document particulate filters after weight record for lab analysis.
  - Obtain 2 one gallon samples for Area lab.
- High DP:
  - Take and retain filtration samples upstream and downstream of Filter/Separator.
  - Obtain 2 one gallon samples for Area lab.
  - Bag filter elements for area lab.
  - Inspect coalescer elements for proper water separation action, clean or replace if coalescent ability is reduced.

Fuel Degraded or Comingled

Conductivity, Flashpoint, API Gravity, FSII, Color, Filtration Time, Coper Strip, Distillation, Existent Gum, Freeze Point, Total Acid, Thermal Stability, Peroxide Number.

Re-sample from failed sample location and re-test.

If failure is repeated evaluate possible extent of contaminant.

Sample upstream and downstream to find extent of suspected contamination.

- Fuel all level and line samples:
  - Divide Fuel sample into two identical samples.
  - Test one bottle for failure condition.
  - Retain second bottle for area lab or Tech team.
  - Obtain 2 one gallon samples for Area lab.
  - Save and document particulate filters after weight record for lab analysis.

Attachment 8

Typical Contaminant Effects on Laboratory Tests

QA test failures must be reported to appropriate area laboratory / operation personnel however prompt use of this table may assist in finding the source of contamination without additional analysis and with a minimum delay. This table contains only typical contaminant effects of QA tests and is by no means complete.

Lighter Product Contamination	
API Gravity	High
Distillation IBP	10% is Low
Reid Vapor Pressure	High
Flash Point	Low
Viscosity	Low
Color Due to Possible AVGAS Comingling	Red, Blue, Green Tint
Heavier Product Contamination	
JFTOT fails	Diesel Comingling
Microseparometer Fails	Possible Oil or Diesel Contamination
Water Reaction Fail	Possible Oil or Diesel Contamination
Filtration Time	High
Freeze Point	Fails Low
Viscosity	High
Existent Gum	High and Oily
Distillation FBP	90% Residue is High
API Gravity	Low
Color Due to Possible Red Diesel Comingling	Red Tint

Deterioration		
API Gravity	Low,	Weathering loss of light ends
Distillation IBP	10% High,	
Reid Vapor Pressure	Low	
Existent Gums	High and Dry	Oxidation
Visual Color Change		
Water & Sediment Contamination		
Visual Test	Hazy	Water
Water Reaction	Fail	
Microseparometer	Fail	
Cloud Point	Fail	
Filtration Time	High	Sediment (fine)
Particulate Test	High	Sediment / Rust
Fiber Content Test	High Fiber Count	Filter Element Failure

Attachment 9

Microbial Contamination Evaluation Using ATP Levels

Current assessments of microbial contamination in AF fuel stocks using the Merck HY-LiTE and IATA aircraft guidelines is inadequate at best and may be seriously misleading. Reliance on Adenosine Tri-Phosphate, (ATP), levels in fuel samples imposes specific requirements on sampling procedure, equipment sterilization, and transport that are absent from recent laboratory reports.

Through historical examination, IATA has determined that a Relative Light Unit, (RLU), reading of less than 1000 may be a normal and tolerable contamination level for aircraft tanks, while a reading greater than 5000 should prompt immediate removal from service for examination and / or biocide treatment.[1] Failure to test frequently or ignoring the potential problem of microbial contamination entirely has led to commercial carriers experiencing flame-out events and aborted flights as well as last minute aircraft changes due to inoperative fuel gauging probes.

The IATA guidelines are accepted by the commercial community for Jet-A/Jet-A1, fuel with limited or no additives, from aircraft's fuel tanks. Not only is this fuel different from Air Force F-24 (NATO F-24), Air Force JP-8 (NATO F-34) and Navy JP-5 (NATO F-44), but the bulk storage tank environment is profoundly different than the aircraft fuel tank environment.

Bacteria and Fungus are predominantly found on fuel tank surfaces or the fuel / water interface. The ratio of tank surface to volume for an aircraft fuel tank is several orders of magnitude greater than that ratio for bulk storage. Fuel in aircraft tanks is in constant movement during flight due to energetic stirring by fuel pumps and aircraft accelerations. Bulk storage tanks are seldom, if ever "well stirred" and may become stratified unless tank usage is high.

Civilian aircraft spend a large part of each day at altitude where the tank temperature approaches freezing, (cold temperatures retard or stop the active growth of microbes). Fuel in Bulk storage changes temperature seasonally. Water bottoms in military fuel tanks, (both aircraft tanks and bulk storage tanks), tend to become saturated with FSII, (typically 20-50%). FSII concentrations in the 10% to 30% range have been shown to be highly toxic to microbes while higher concentrations overwhelm microbes by osmotic pressure, rupturing cell walls on contact.[2,3] Dormant spores, encysted microbes or biofilms not directly in contact with high FSII concentrations are all possible reservoirs for downstream contamination. Finding any microbial evidence in bulk storage indicates that the FSII content is no longer providing sufficient antimicrobial protection for downstream fuel system components. In 2003 AFRL initiated a study to investigate microbial contamination levels in JP-8 fueled aircraft. Eleven different airframes were sampled at 12 different air bases across the US. Fuel samples were collected from over 200 fuel tanks in 75 operational, CONUS based Air Force aircraft.[4] Beginning in 2010, DLA funded a study through AFRL to monitor microbial levels at four CONUS installations during their change over from receiving JP-8 to receiving Jet-A with on-base additization.

Microbial contamination levels in fuel storage tanks and fuel delivery systems as well as aircraft fuel tanks were monitored at McChord-Lewis Joint Base, Little Rock AFB, MPLS-St. Paul ANG-Reserve base, and Dover AFB. The initial visits were made while these installations were receiving JP-8 from their refinery sources and continued after their fuel receipts were changed to Jet-A with on base additive injection. Figure 1 shows the frequency of responses to the HY-LiTE ® ATP test performed on a combined total of 465 fuel samples from aircraft fuel tanks over a period of 7 years.

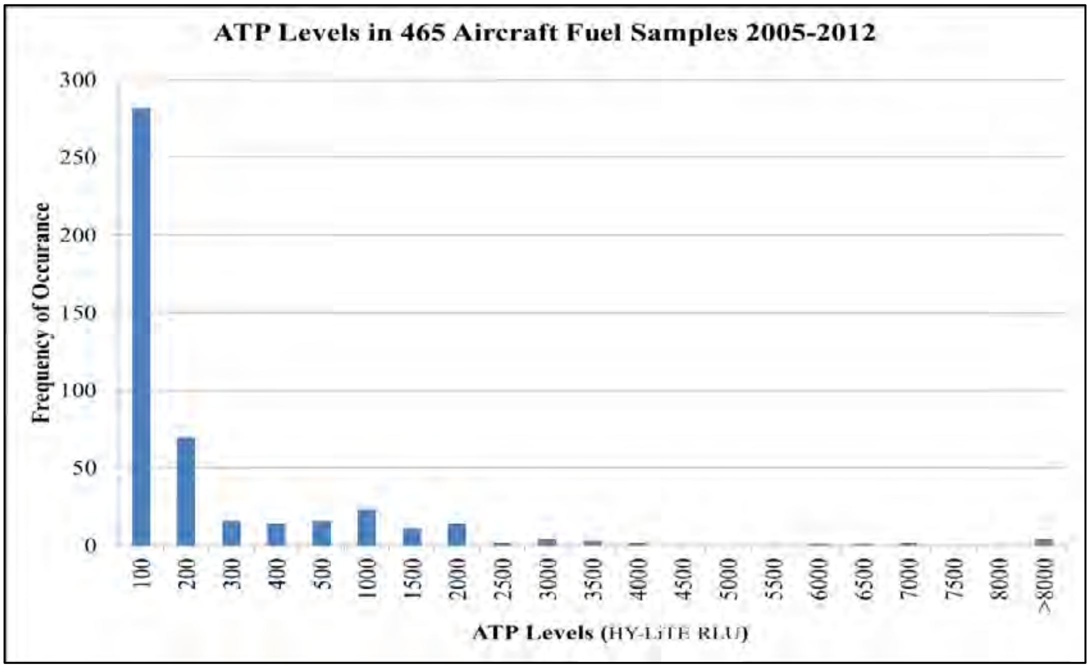


Figure 1. Aircraft ATP Levels

Data from the combined studies leads to the conclusion that a "normal" response to the HY-LiTE ® ATP test on aircraft fuel samples should be less than 500 RLU. Aircraft tanks testing higher than 500 RLU should be re-tested after refueling to eliminate random outlier responses. Establishing an upper limit for normal operations would involve testing fuel from all aircraft reporting fuel tank contamination or fuel probe fouling to determine immediate response "high" level. However, any repeatable elevated ATP levels found in fuel samples containing FSII should be treated as significant and considered to be abnormal.

Visual and ATP evaluations of fuel and water bottoms from aircraft (Figure 1), storage tanks (Figure 2), filter-separators and bulk storage, (Figure 3), were documented. No trends were discerned that could be linked to the JP-8 to Jet A transition, however the data does support proposing a lower watch limit of 500 RLU for JP-8 or F-24 samples from fuel storage tanks.

Figure 3 also contains 14 instances of ATP measurements over 1000 RLU at Dover AFB while they were dealing with very high levels of microbial contamination in their bulk storage and hydrant supply tanks. Multiple product recovery operations per day and circulating fuel supplies through filter separation units resulted in return to normal ATP levels (less than 500 RLU), within several days. Levels above 500 should trigger additional testing and emphasis on water removal.

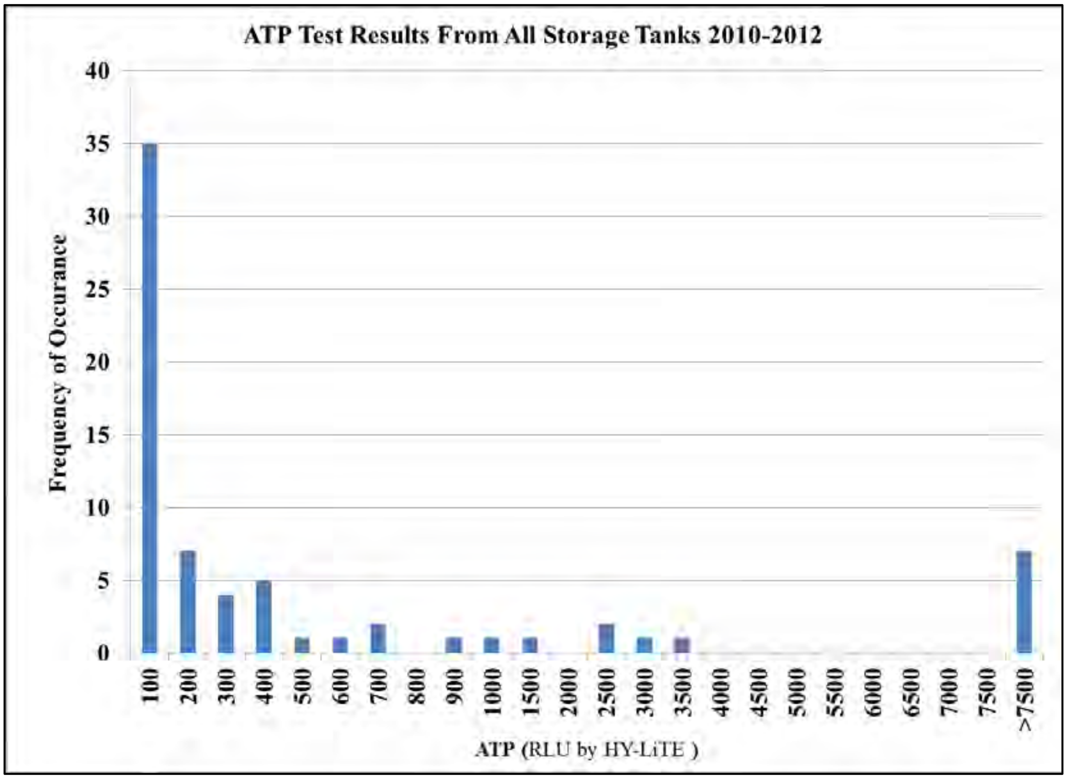


Figure 2. Fuel Storage Tank ATP Levels

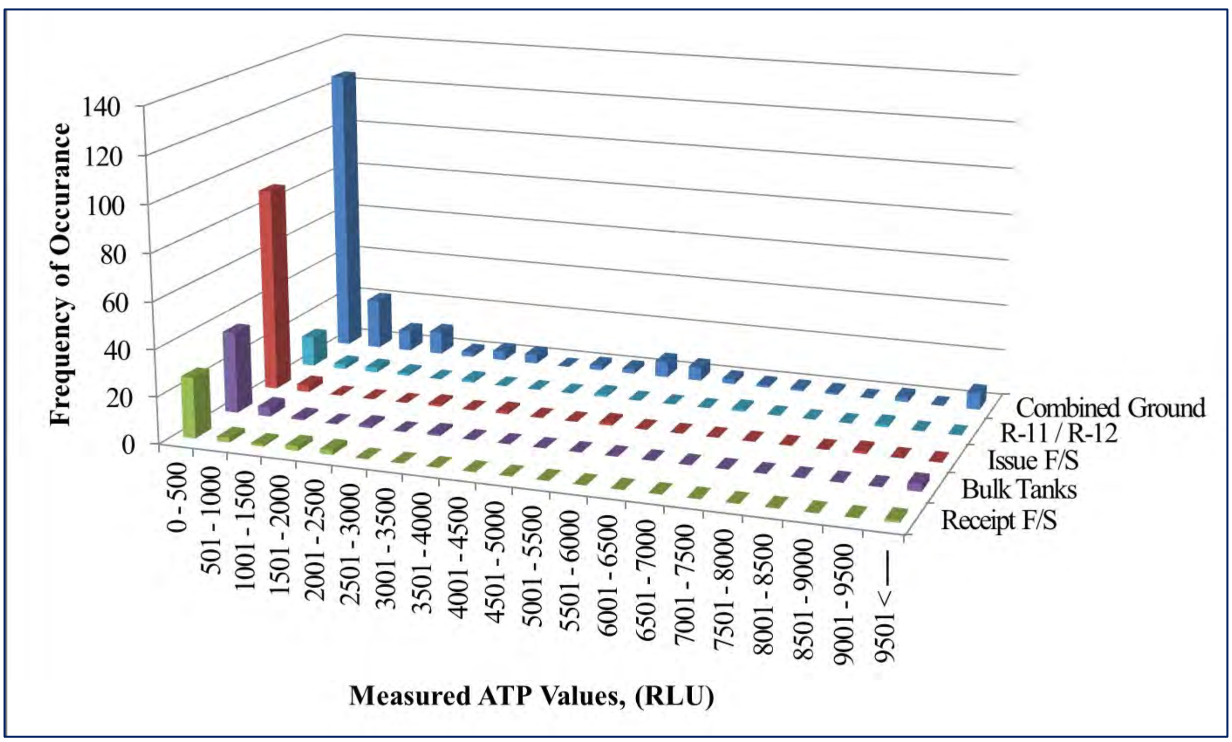


Figure 3: Combined ATP measurements from fuel storage and filtration systems during 2010 - 2012.

Prepackaged Microbial Sampling Kit Materials:

- Six pre sterilized 1l HDPE bottles.
- Six bottle tags to identify sample.

Sample capture and preparation instructions.

- Insulated return shipment container large enough to hold 6 1l bottles and 6 cold packs, (cold packs can be chemically activated or freezer type cold packs).
- Packing material sufficient to adsorb and contain fuel if bottles rupture in transit.
- Chain of Custody form with room for complete description of sample condition and source.

Sampling Procedure: Operational aircraft

(Aircraft Incident sampling procedures are located in TO 42B-1-1.)
If no prepackaged sampling supplies are available follow instructions in D-6469 to clean sample containers.

- Locate personnel capable of preparing hazardous shipping documents. Trained personnel must prepare documents and certify that proper packaging directives have been followed. Sample should be drawn and packaged immediately before delivery to overnight shipper.
- Open kit and remove cold packs – place freezer type packs in the freezer.
- Organize PPE, denatured ethanol in an appropriate dispenser, sterilized sample bottles, fuel absorbent towels.

<u>Aircraft fuel tank sample:</u>

(Aircraft samples should be taken from each main tank or engine feed tank. If only one tank is being sampled, take two 0.75ℓ from the same sump and mix together to get two equivalent samples. If the entire aircraft is suspect then take samples from all tanks and use leftover bottles for duplicate samples. 6 samples should be sufficient to reveal any contamination issues within an aircraft. If contamination is found in any tank, all untested tanks should be tested also.)

- Wipe sump port with denatured ethanol, rinse pogo stick or sump tool with denatured ethanol and air dry.
- Capture 0.75 ℓ (approx.) of initial fluid into each bottle. ()

<u>Bulk storage or delivery system samples:</u>

- Organize PPE, denatured ethanol in an appropriate dispenser, sterilized sample bottles, towels.
- Wipe sump port with denatured ethanol, rinse sampling tubes with denatured ethanol and air dry.
- If sampling port contains old fuel drain an equivalent amount to ensure the sample is from the sump.
- Capture 0.75 ℓ (approx.) of initial fluid into each bottle.
- Capture additional set of tank bottom or sump samples downstream from initial test site and one set upstream if there is an available location).

<u>All Samples:</u>

- Identify each bottle with a sample number or letter tag. Reference each tag id. on Chain of Custody sheet with operator id, time, location, weather (wind, rain, etc.), content description (cloudy, clear, two phase, rag layer, etc.)
- Pack fuel in absorbent material, (<u>not vermiculite!</u>), in insulated container with cold packs and Chain of Custody form.
- Store fuel in a refrigerator until shipment pickup.

- Deliver to overnight shipper for delivery within 24 hours to a laboratory that has experience with fuel microbiology.
- Contact destination laboratory with tracking number and the need for immediate processing.

Microbial test kits provide a useful method to track contamination levels only if the complete procedure remains the same for all samples. Any deviation from standard protocols will produce a increased level of uncertainty in the results. For this reason, any preventive testing program should be designed by personnel familiar with microbiological laboratory procedures or specialized training in field testing for microbial contamination in fuel systems.

Any elevated level contamination measured should be confirmed after at least one refueling to eliminate transient results prior to taking any remediation action. Sample locations should be chosen to provide coverage to all major storage locations and water separation sumps. Random location sampling is self-defeating in that expensive resources will be consumed while providing limited historical tracking and increased probability of missing other contaminated fuel streams. Table 1 lists the major microbial test kits used internationally along with general level of contamination they will measure.

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1 Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks, IATA 3rd Edition, June 2009.

2 Effects of Diethylene Glycol Monomethyl Ether (DiEGME) and Triethylene Glycol Monomethyl Ether (TriEGME) on Microbial Contaminants in Aviation Fuel, AFRL-RZ-WP-TR-2010-2094.

3 he Effect of DiEGME on Microbial Contamination of Jet Fuel: A Minimum Concentration Study, AFRL-RZ-WP- TR-2010-2002

4 Microbial Contamination Studies in Jp-8 Fueled Aircraft, International Conference on Stability, Handling and Use of Liquid Fuels, October 2007.

Table 1. Microbial Contamination Test Kits Used Worldwide

Nations	Name of the product	Incubation	Organism detected			Remarks
			Bacteria	Yeasts	Fungi	
BEL, CZE, NLD	EASICULT COMBI (Orion Diag.)	96 h / Yeasts	10^3/ml	10^2/ml	Slight	Product is unfit for use if **ONE OF THE THREE** levels of contamination is reached.
CAN	HY-LiTE Jet A1	None	"-Negligible < 1000 RLU/litre -Moderate 1000 - 5000 RLU/litre -Heavy >5000 RLU/litre			* IATA recommended method for testing of total microbiological activity in fuel phase, water phase, or in mixed fuel/water interface. If biological activity is detected and further investigation is required then Sani- Check BF and Sani-Check YM can be employed to represent the abundance of bacteria and/or fungi (BF) in conjunction with yeasts and/or molds (YM).
DEU, PRT	Cult-Dip combi (Merck)	48 h / Bacteria 72 h / Yeasts and Fungi	10^3 /ml	Slight to moderate	Slight to moderate	Product is unfit for use if **ONE OF THE THREE** levels of contamination is reached.
DNK	Liquicult (MCE)					
FRA	S-1752 (MICROTEST P)	96 h / Yeasts	Serious	Serious	Slight Moderate Serious	Product is unfit for use if **ONE OF THE THREE** levels of contamination is reached.
			Moderate	Moderate	None	Product is unfit for use if Bacteria and Yeasts are both moderate.
USAF	Merck HY-Lite	None	"Negligible < 1000 RLU/litre Moderate 1000-5000 RLU/litre Heavy > 5000 RLU:litre			Limits used in accordance with IATA guidance for aircraft. The decision to treat affected aircraft is done on a case by case basis and the final authority lies with the weapon system managers